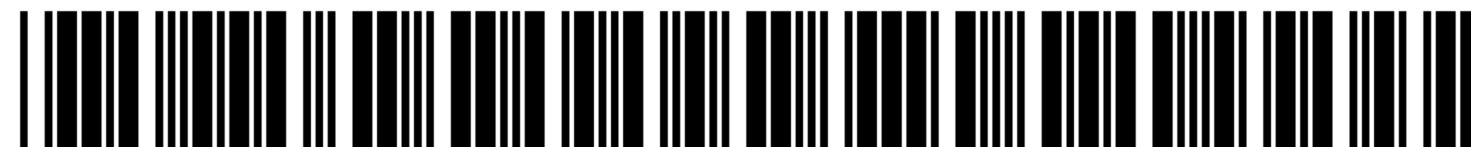

(12) **United States Patent**
Kajiyama et al.

(10) **Patent No.:** **US 9,207,546 B2**
(45) **Date of Patent:** **Dec. 8, 2015**

(54) **EXPOSURE METHOD AND EXPOSURE APPARATUS**

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(73) Assignee: **V TECHNOLOGY CO., LTD.**, Kanagawa (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 752 days.

(21) Appl. No.: **13/495,668**

(22) Filed: **Jun. 13, 2012**

(65) **Prior Publication Data**

US 2012/0249993 A1 Oct. 4, 2012

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2010/071281, filed on Nov. 29, 2010.

(30) **Foreign Application Priority Data**

Dec. 14, 2009 (JP) 2009-283067

(51) **Int. Cl.**
G03B 27/44 (2006.01)
G03B 27/42 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G03F 7/70725*** (2013.01); ***G03F 7/7035*** (2013.01); ***G03F 7/70358*** (2013.01); ***G03F 7/70433*** (2013.01); ***G03F 7/70533*** (2013.01)

(58) **Field of Classification Search**
CPC G03F 7/70275; G03F 7/70283; G03F 7/70291; G03F 7/7035; G03F 7/70358; G03F 7/70391; G03F 7/704; G03F 7/70433; G03F 7/70533; G03F 7/70725; G03F 7/2022; G03F 7/203
USPC 355/46, 52, 53, 55, 72–77; 250/492.1, 250/492.2, 492.22, 548; 430/5, 8, 22, 30, 430/311, 312, 321, 394
See application file for complete search history.

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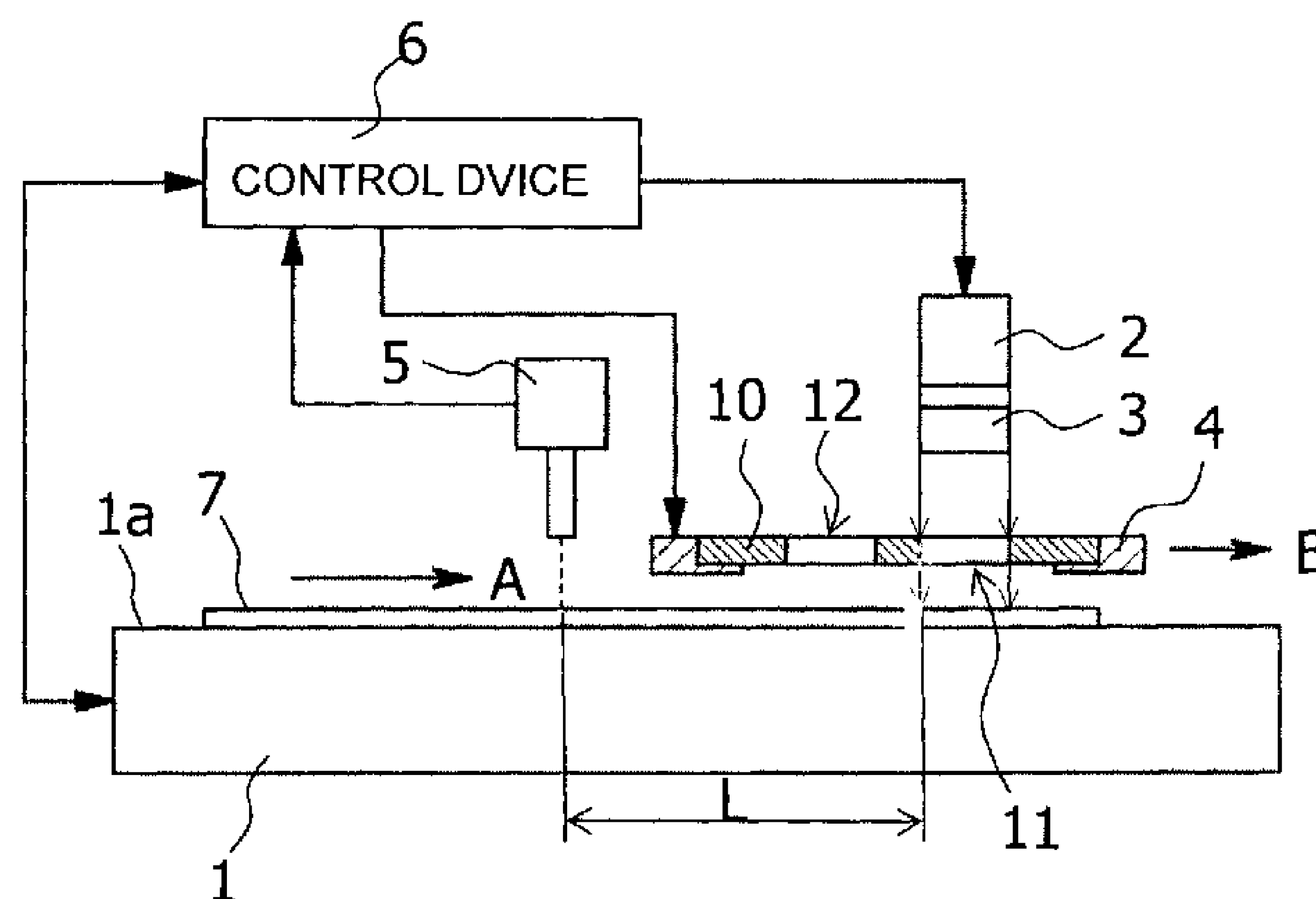
(74) *Attorney, Agent, or Firm* — Finnegan, Henderson, Farabow, Garrett & Dunner LLP

(57) **ABSTRACT**

An exposure method includes a step of moving a photomask by a predetermined distance and switching a first mask pattern group to a second mask pattern group when an exposure to a first exposure area on an object to be exposed by the first mask pattern group of the photomask formed by arranging the first and the second mask pattern groups corresponding to an exposure patterns at predetermined intervals in a conveying direction of the object to be exposed is completed, and a step of performing an exposure on the second exposure area on the object to be exposed by the second mask pattern group, in which a moving speed of the photomask is controlled so that a moving distance of the object to be exposed is longer than a moving distance of the photomask in a period of time when switching the first and the second mask pattern groups.

10 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

G03B 27/32	(2006.01)
G03F 7/20	(2006.01)
G03B 27/52	(2006.01)

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FIG.1

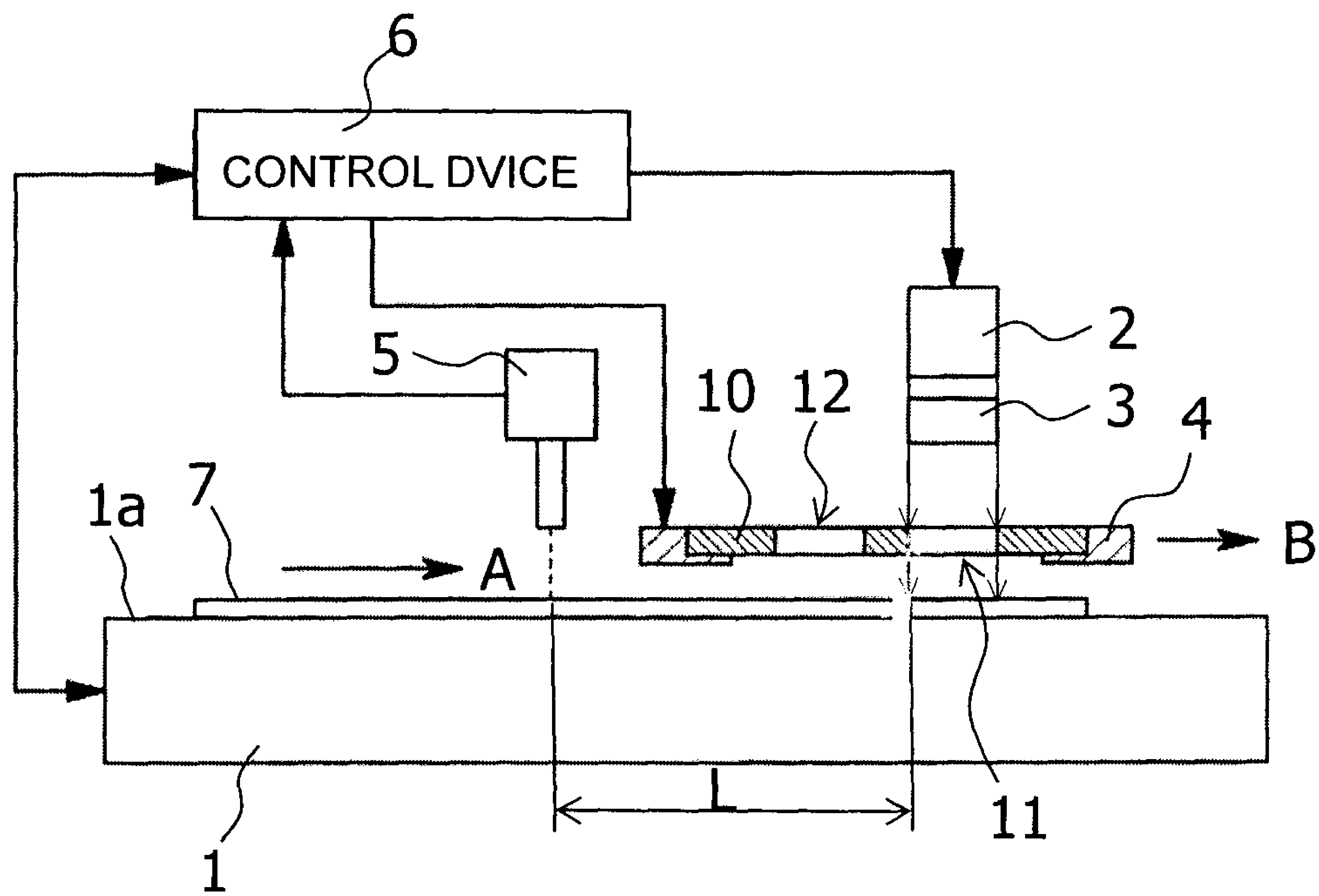


FIG.2

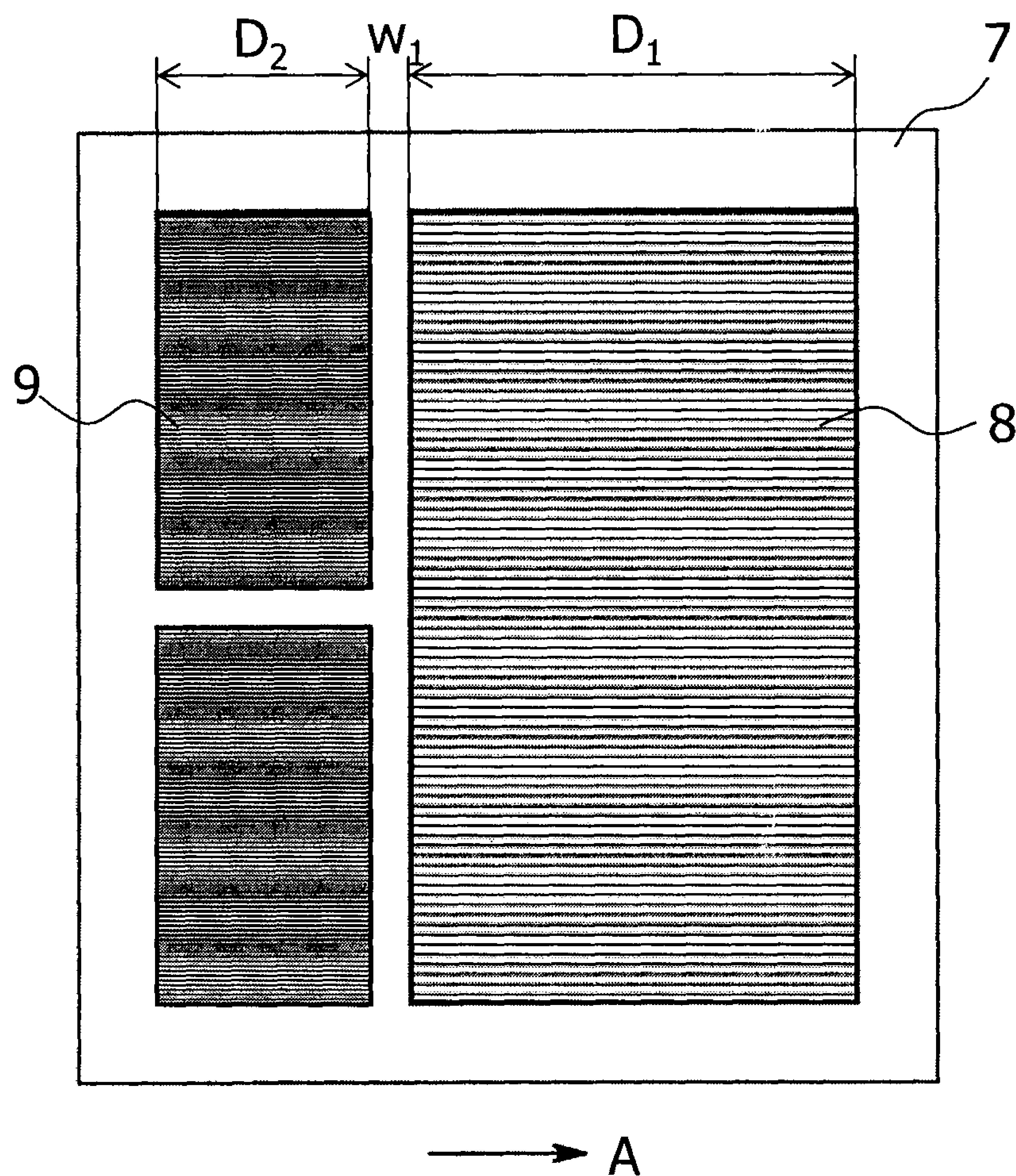
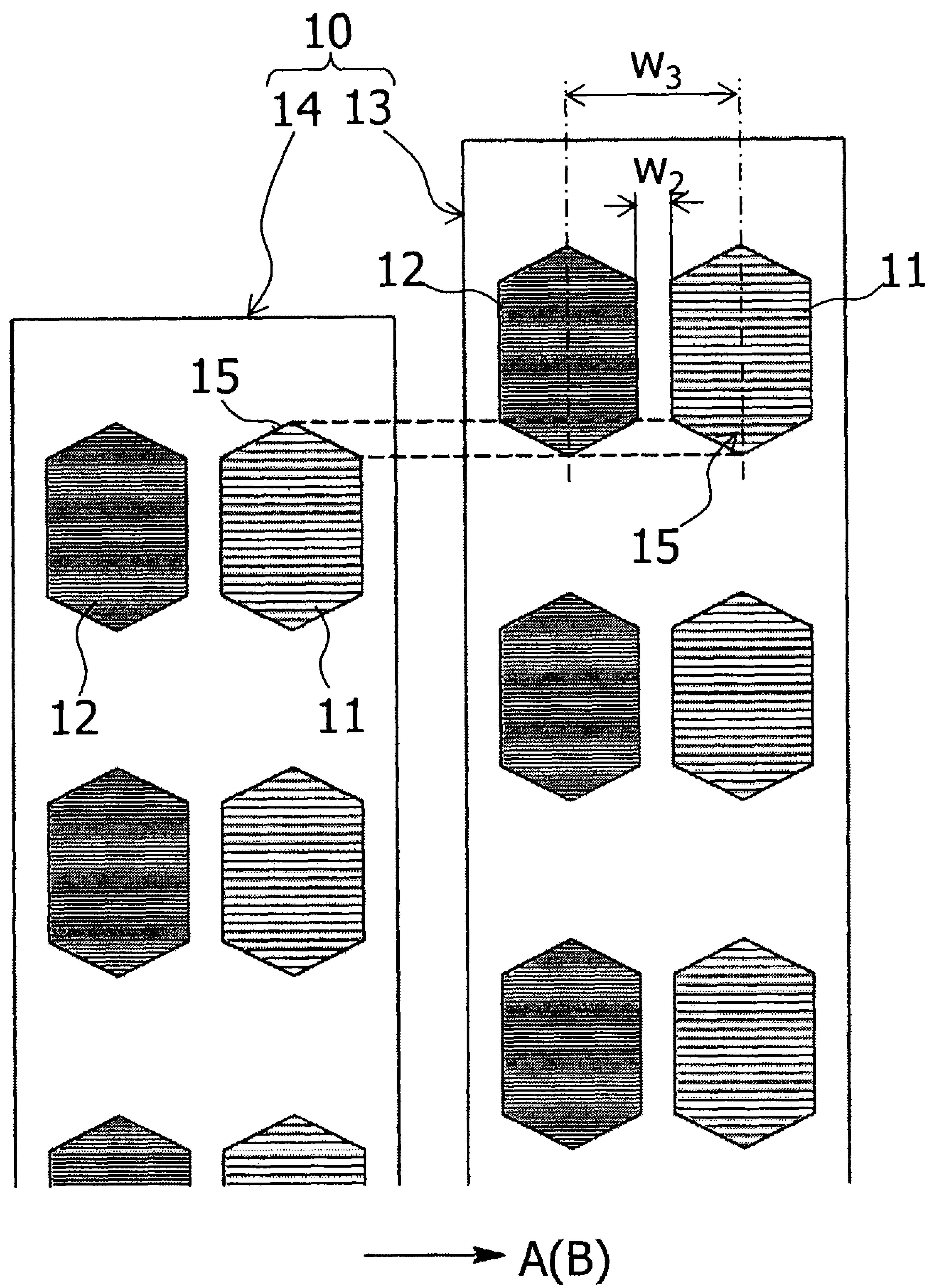


FIG.3



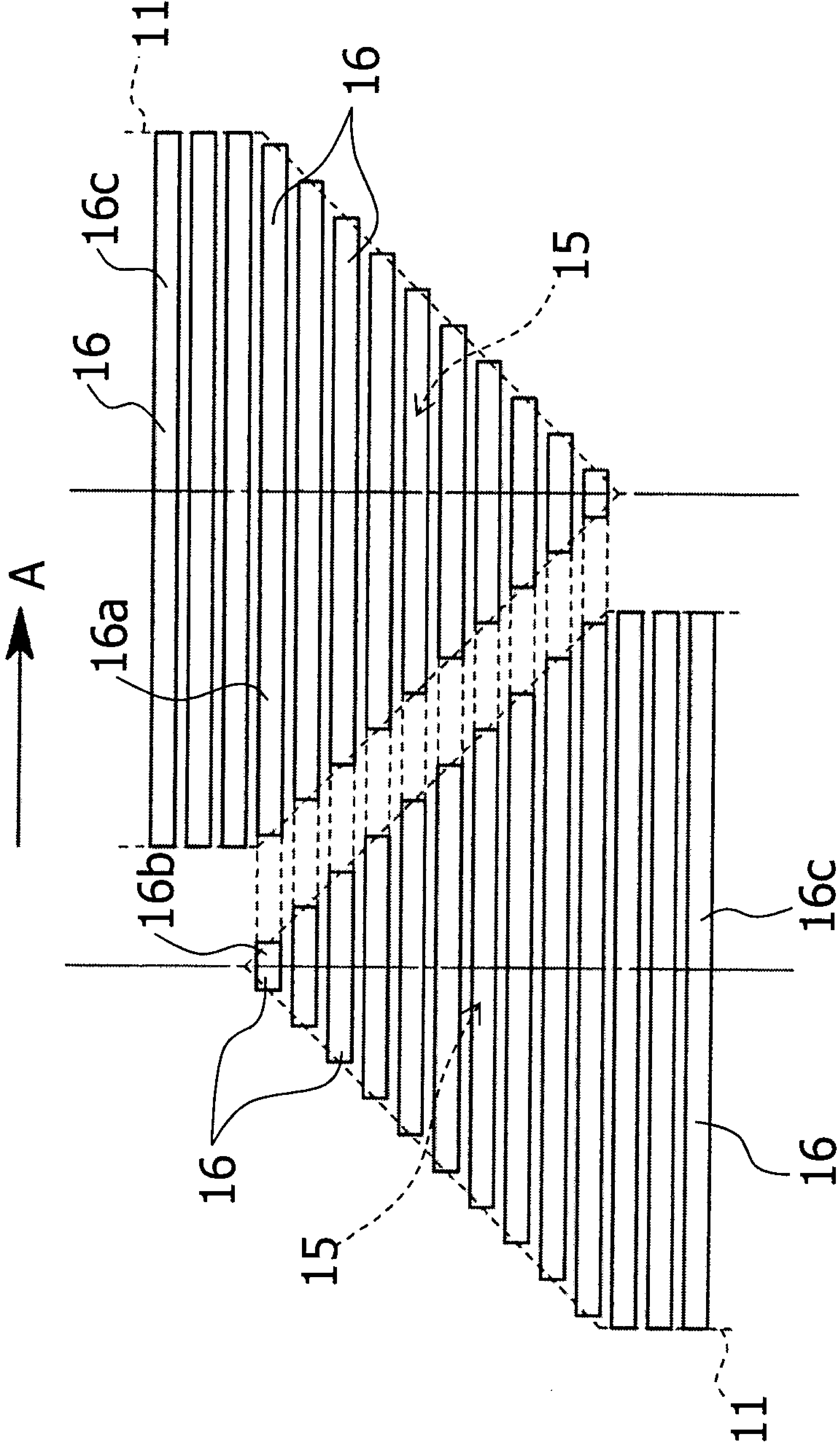
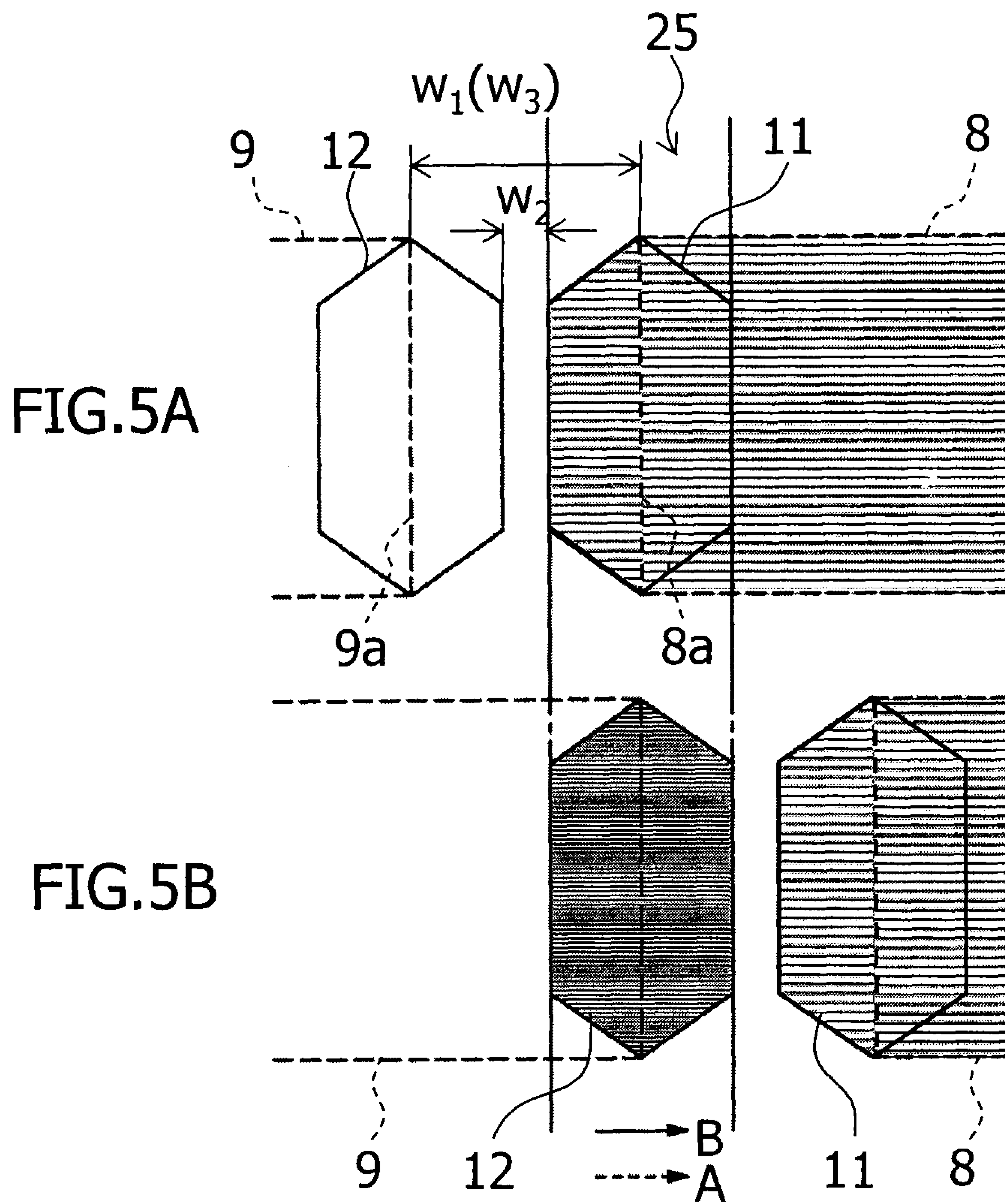
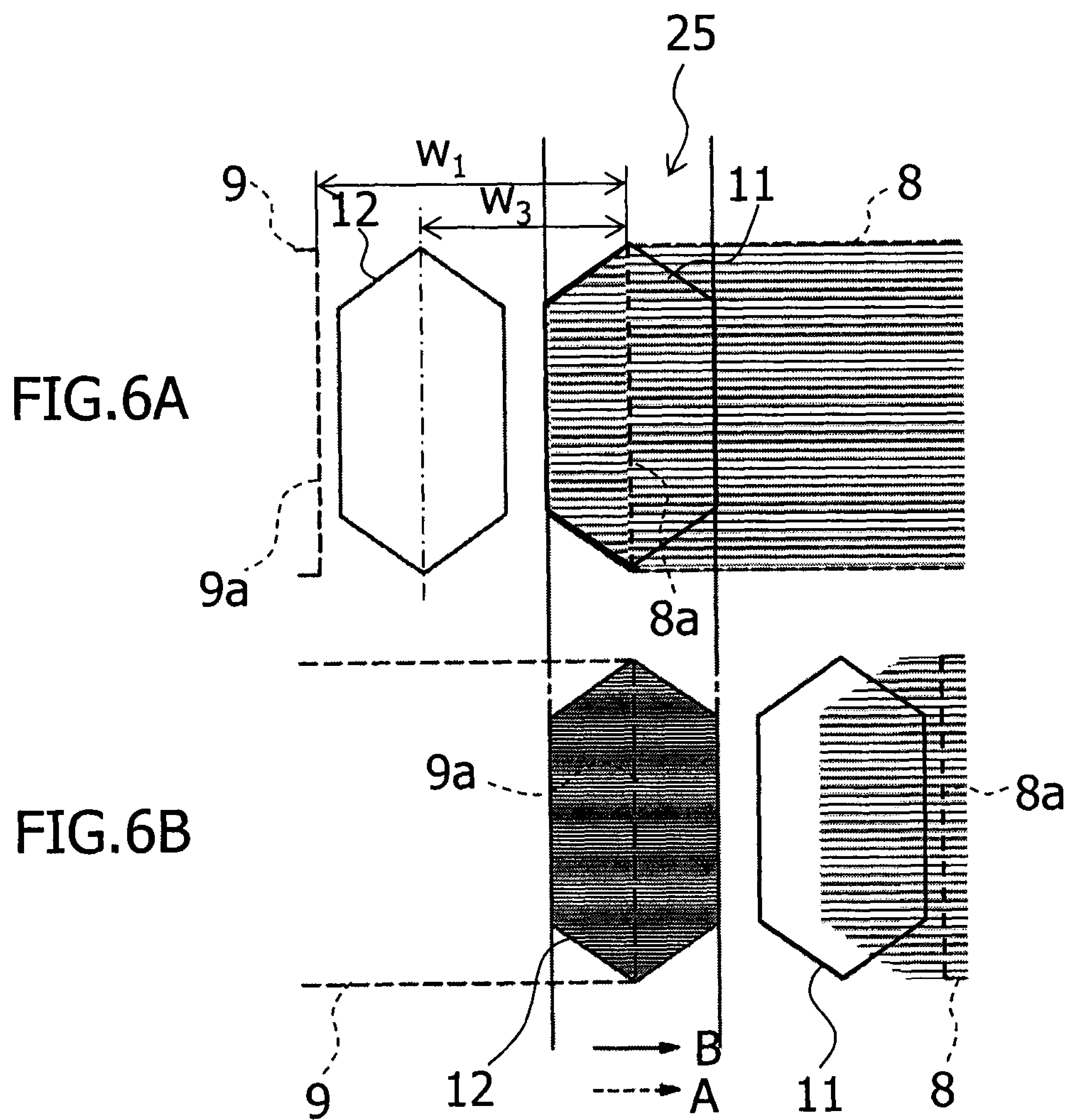


FIG.4
A
11
16
16c
16
15
16a
16b
16c
16
16
15
11


25
w1(w3)
9
12
w2
11
8
FIG.5A
9a
8a
FIG.5B
9
12
B
A
11
8


25
W_1
W_3
9
12
11
8
FIG.6A
9a
8a
9a
8a
FIG.6B
B
A
9
12
11
8

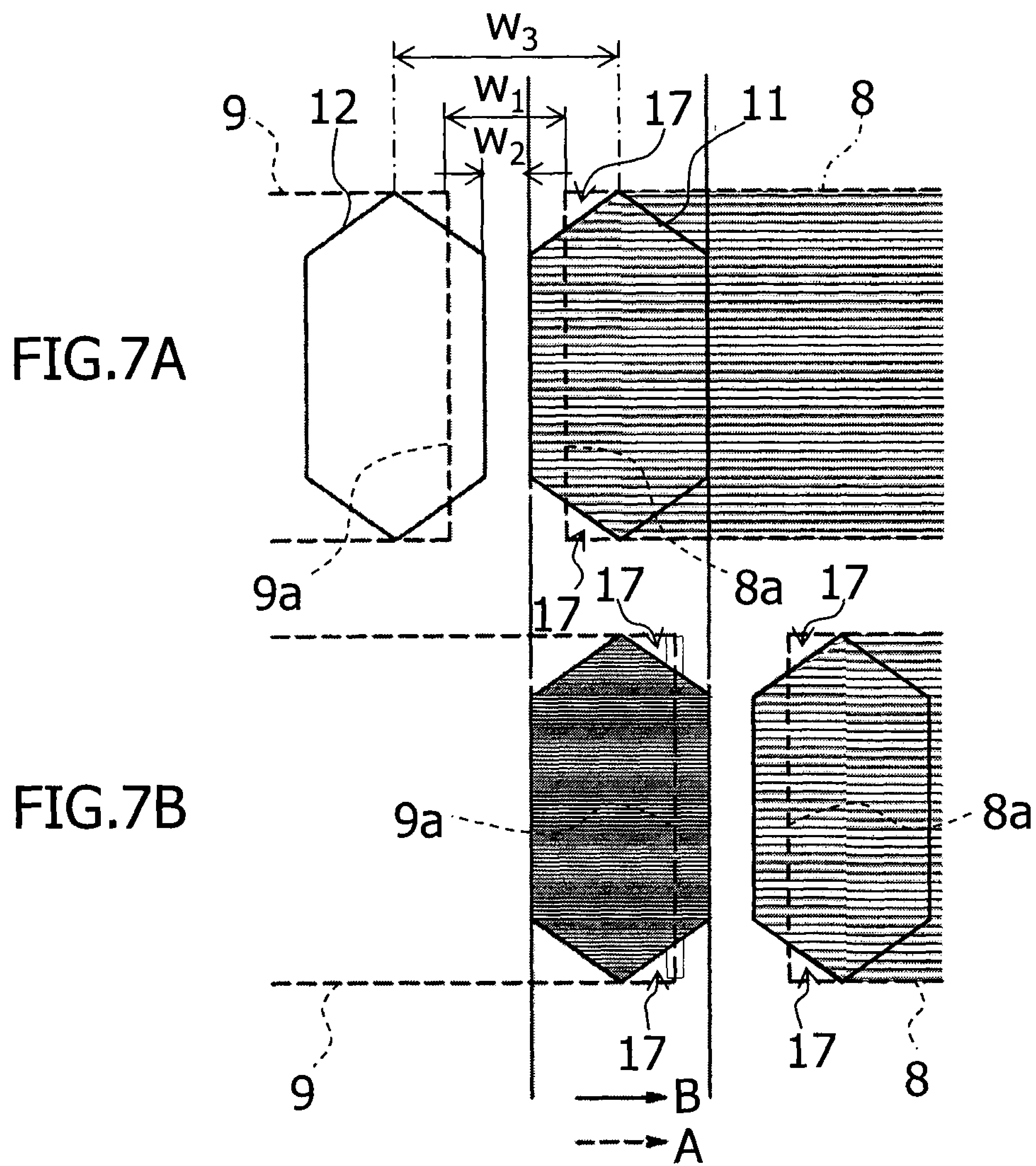


FIG.7A
FIG.7B
W_3
W_1
W_2
9
12
17
11
8
9a
8a
17
17
17
9a
8a
17
17
9
8
B
A

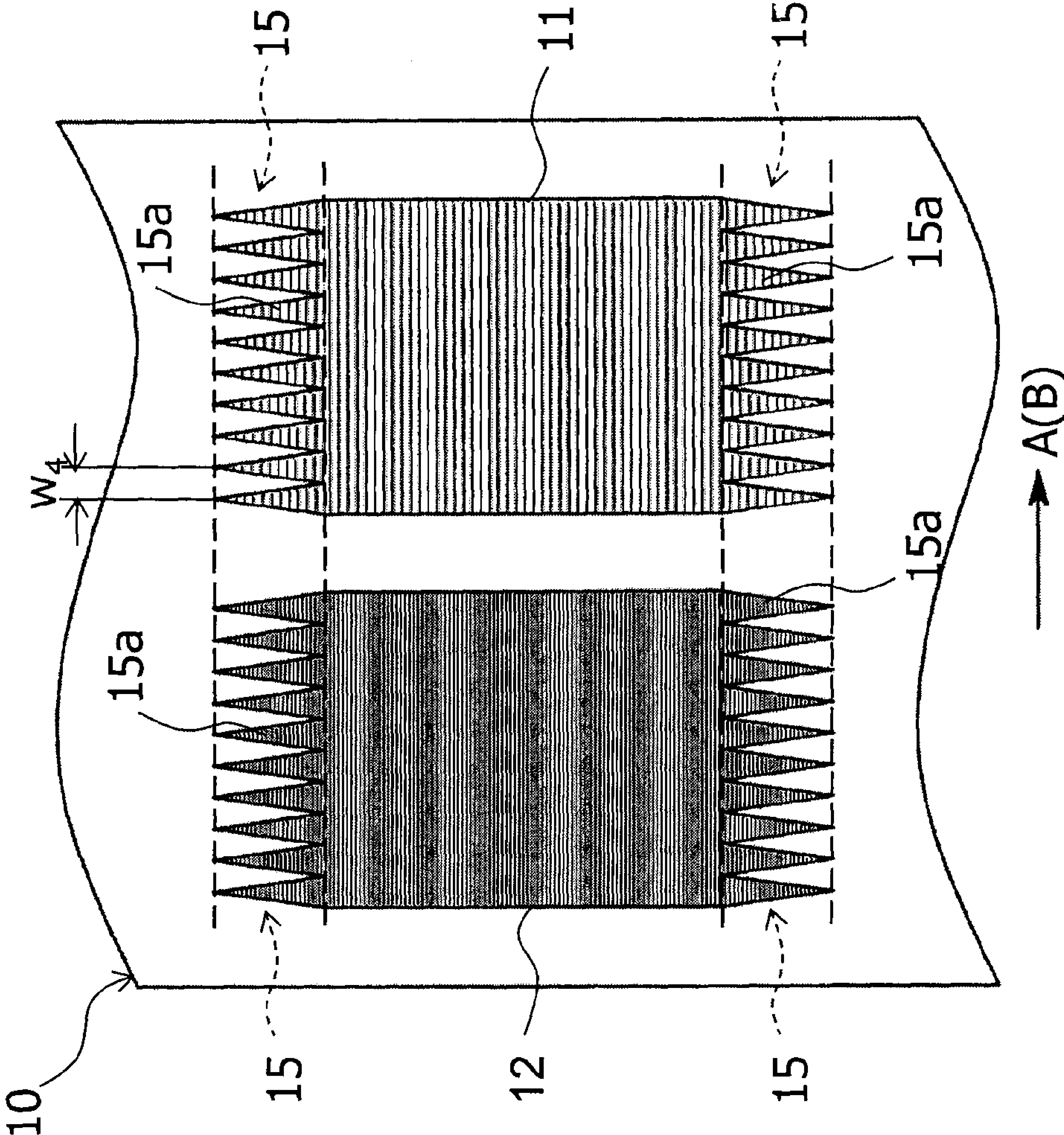


FIG.8
10
15
12
15
15a
15a
W_4
15
11
15
15a
15a
A(B)

FIG.9

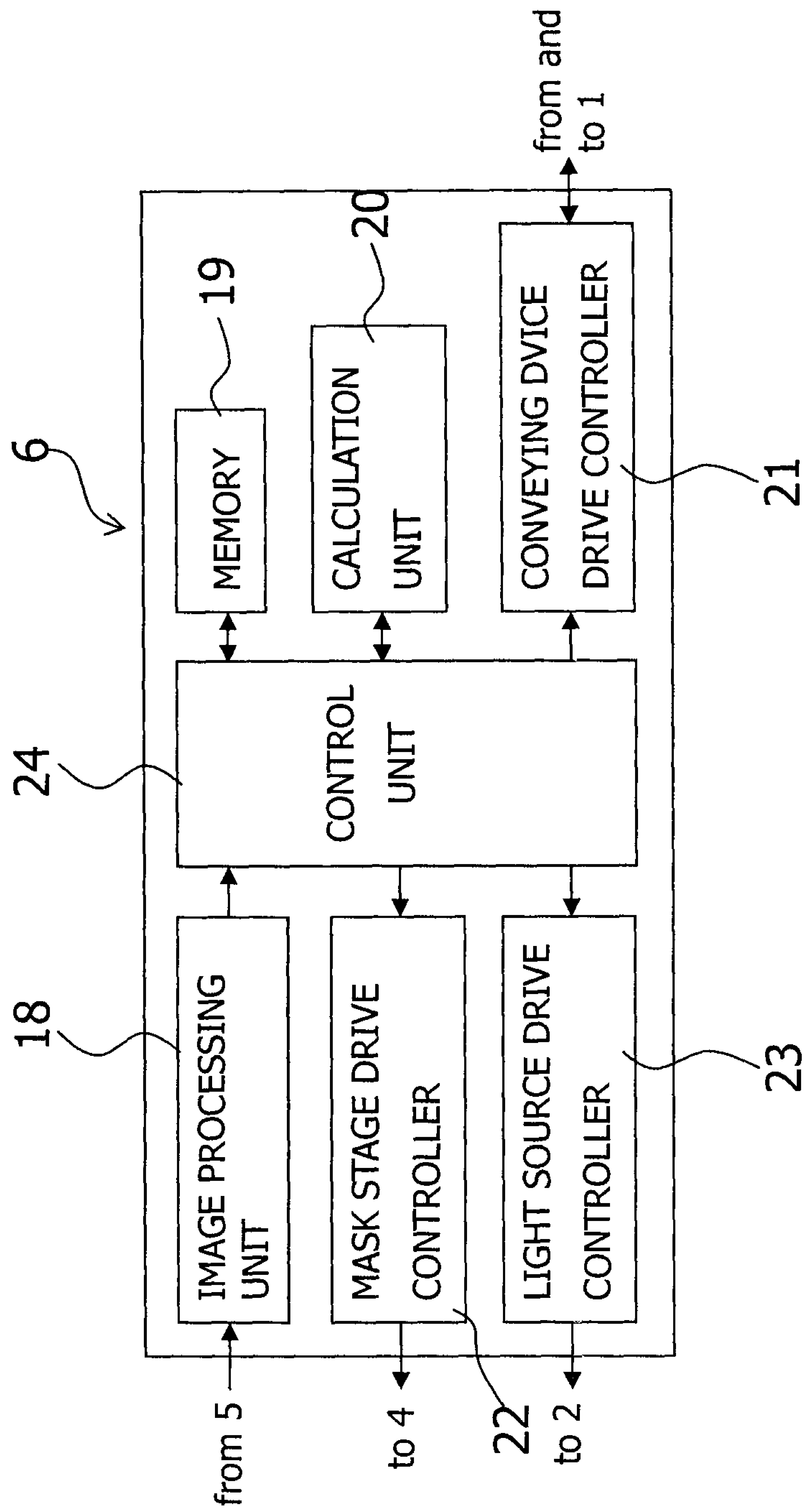
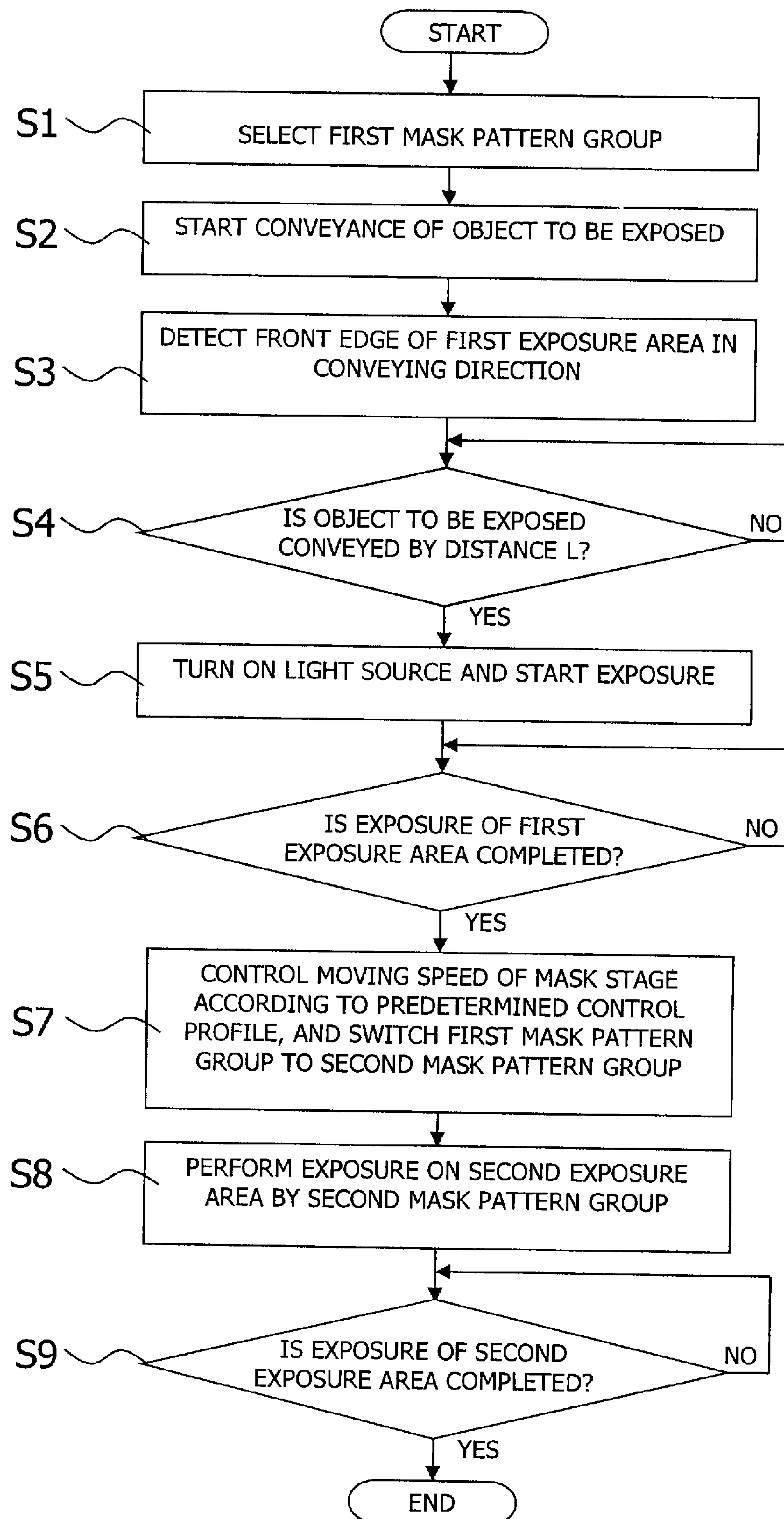


FIG.10



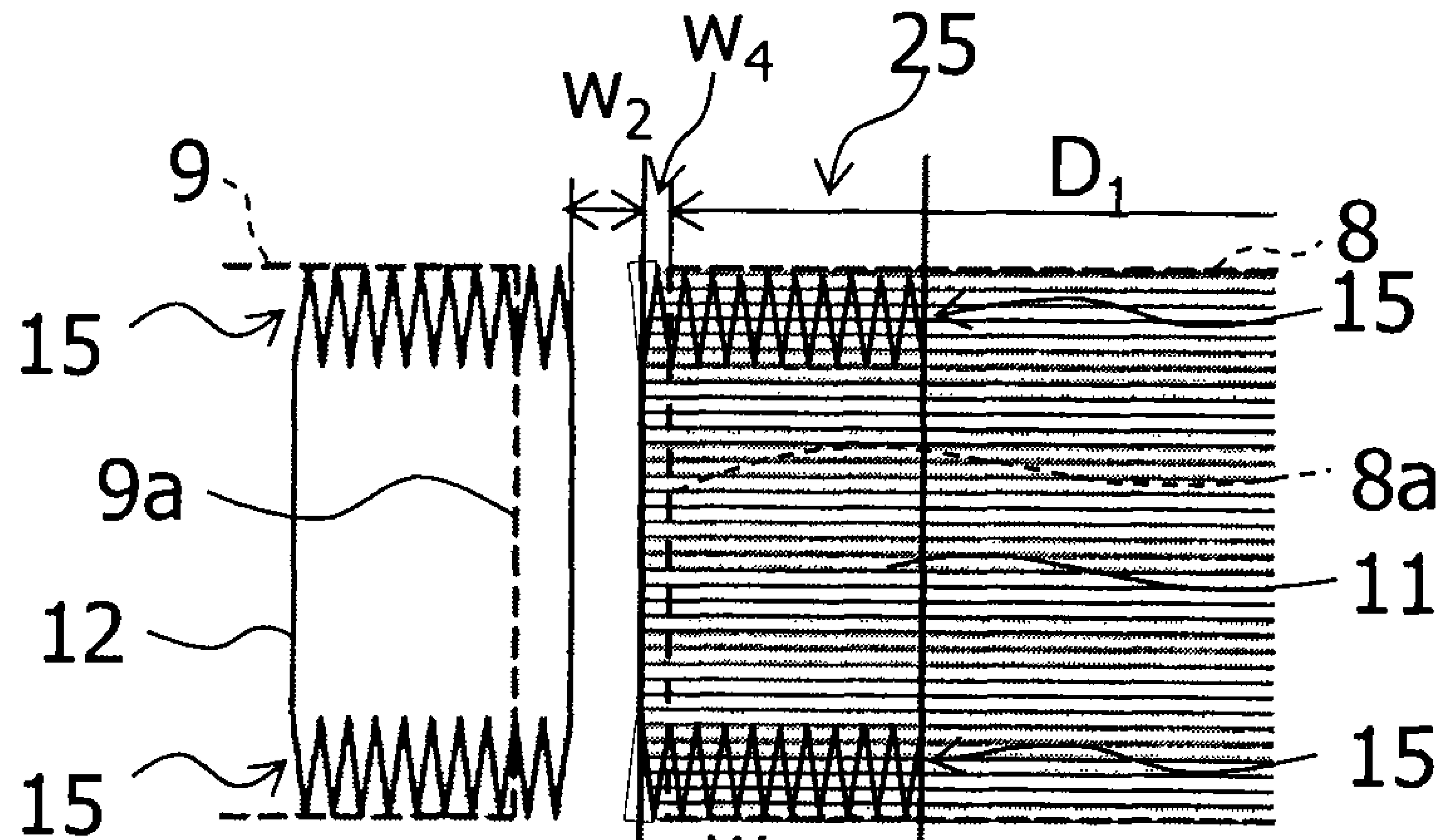


FIG.11A

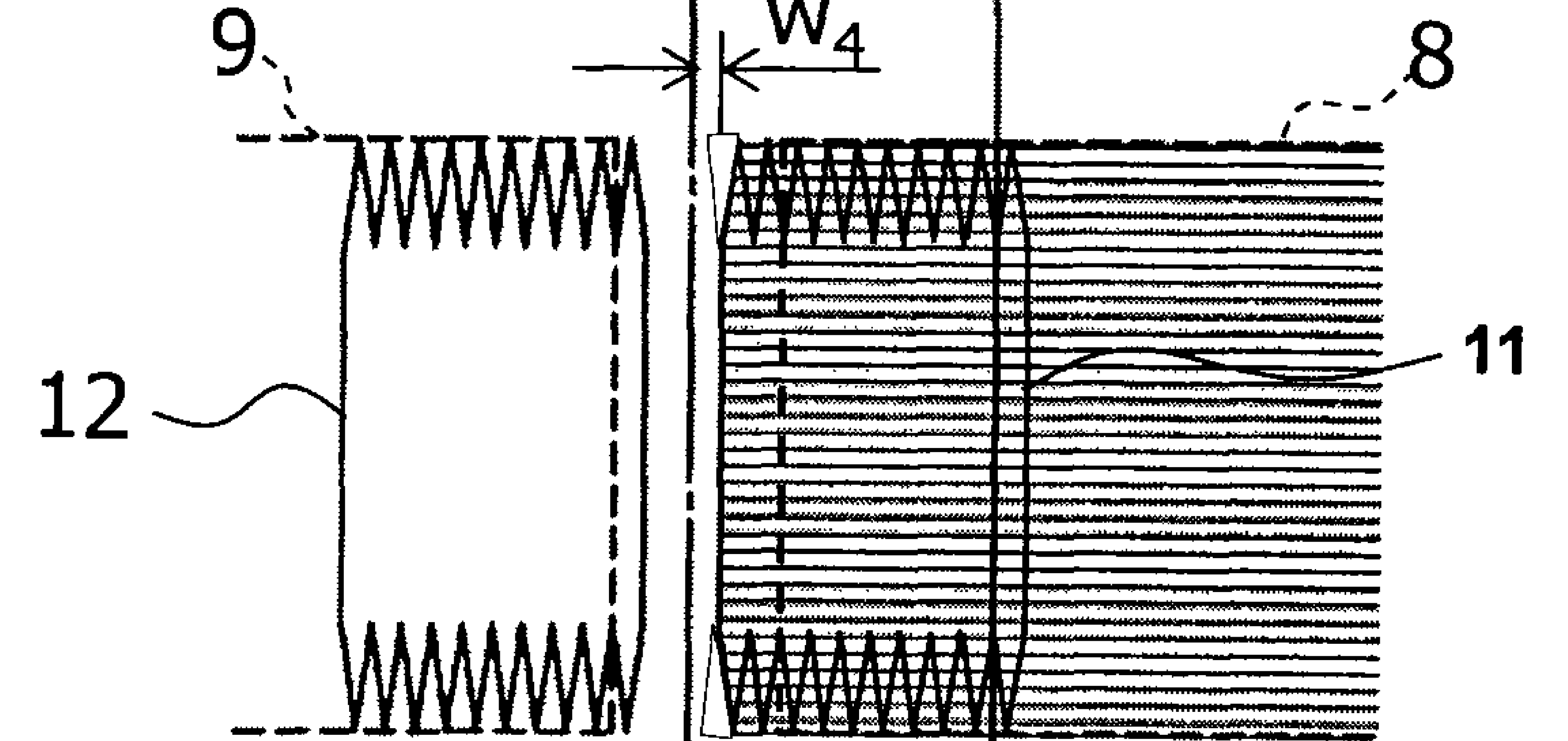


FIG.11B

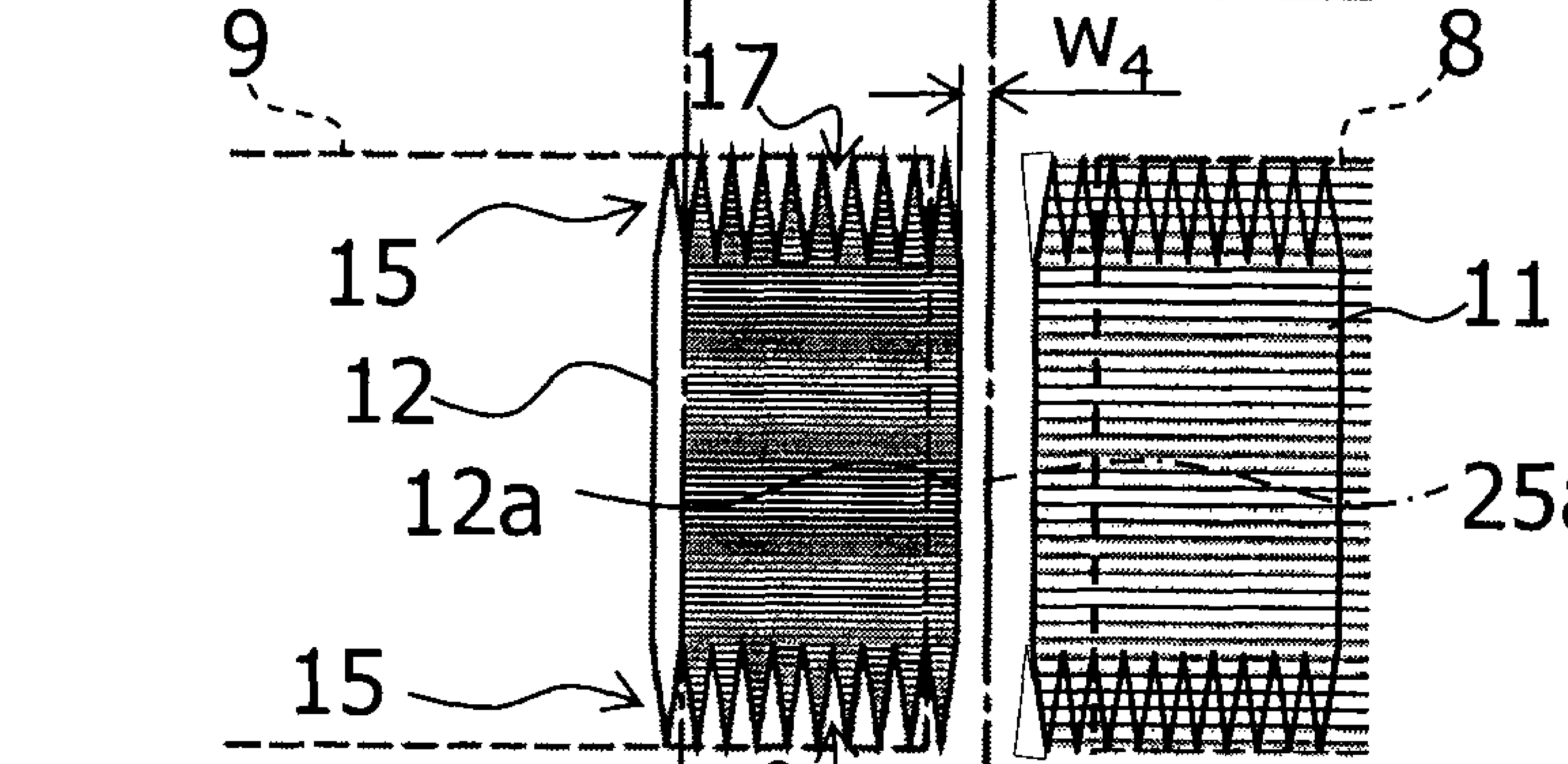


FIG.11C

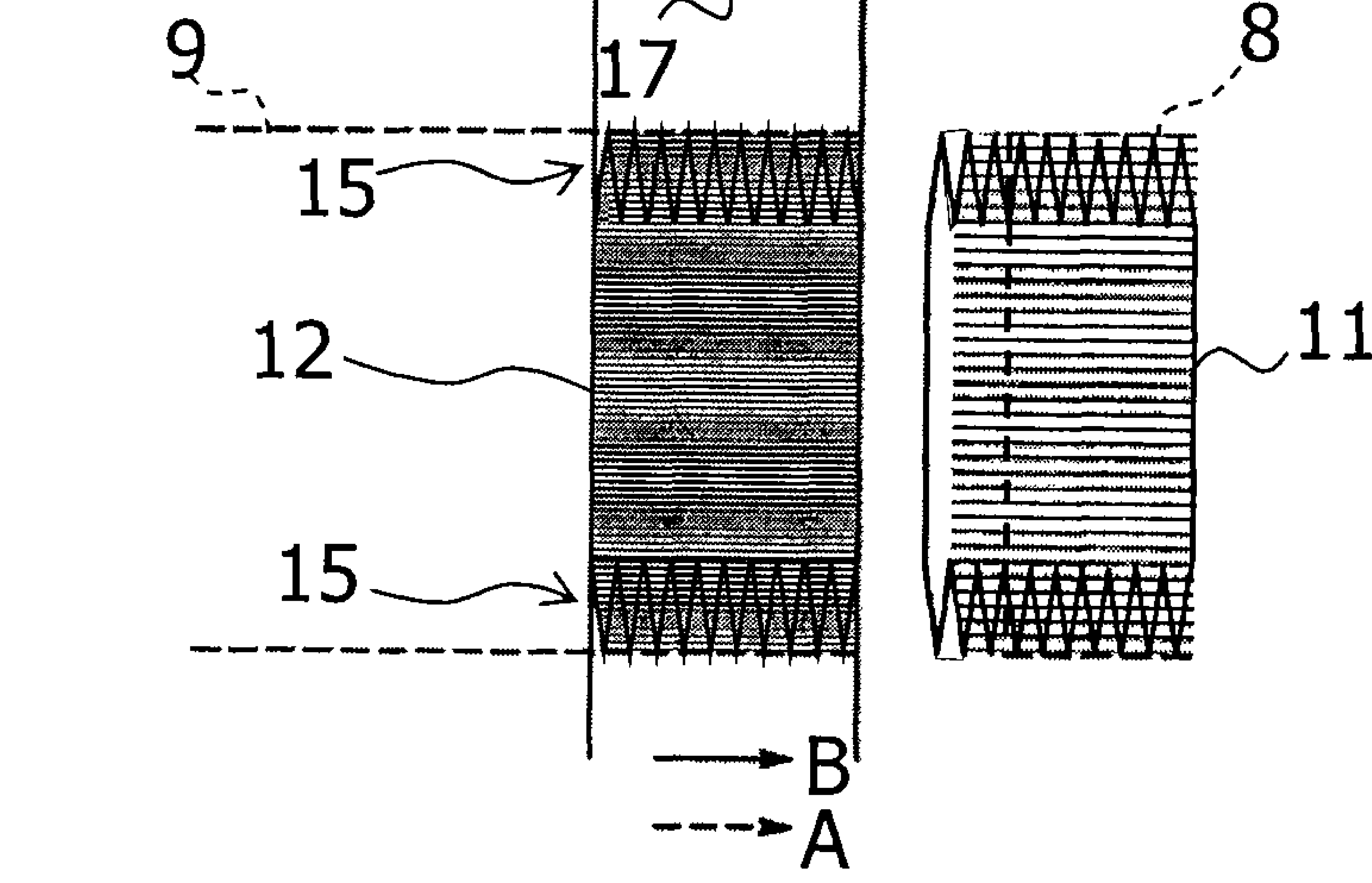


FIG.11D

FIG.12

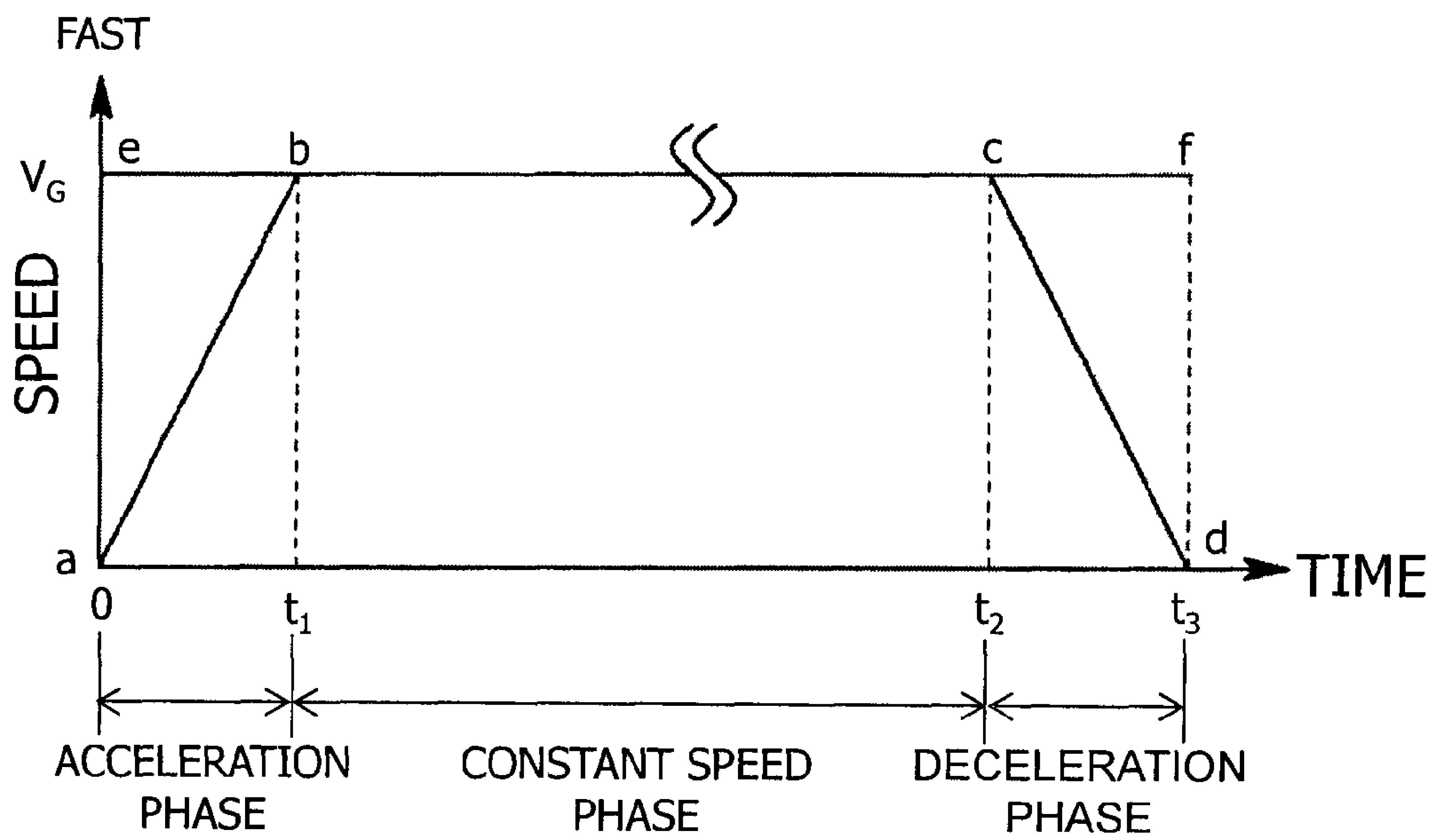


FIG.13

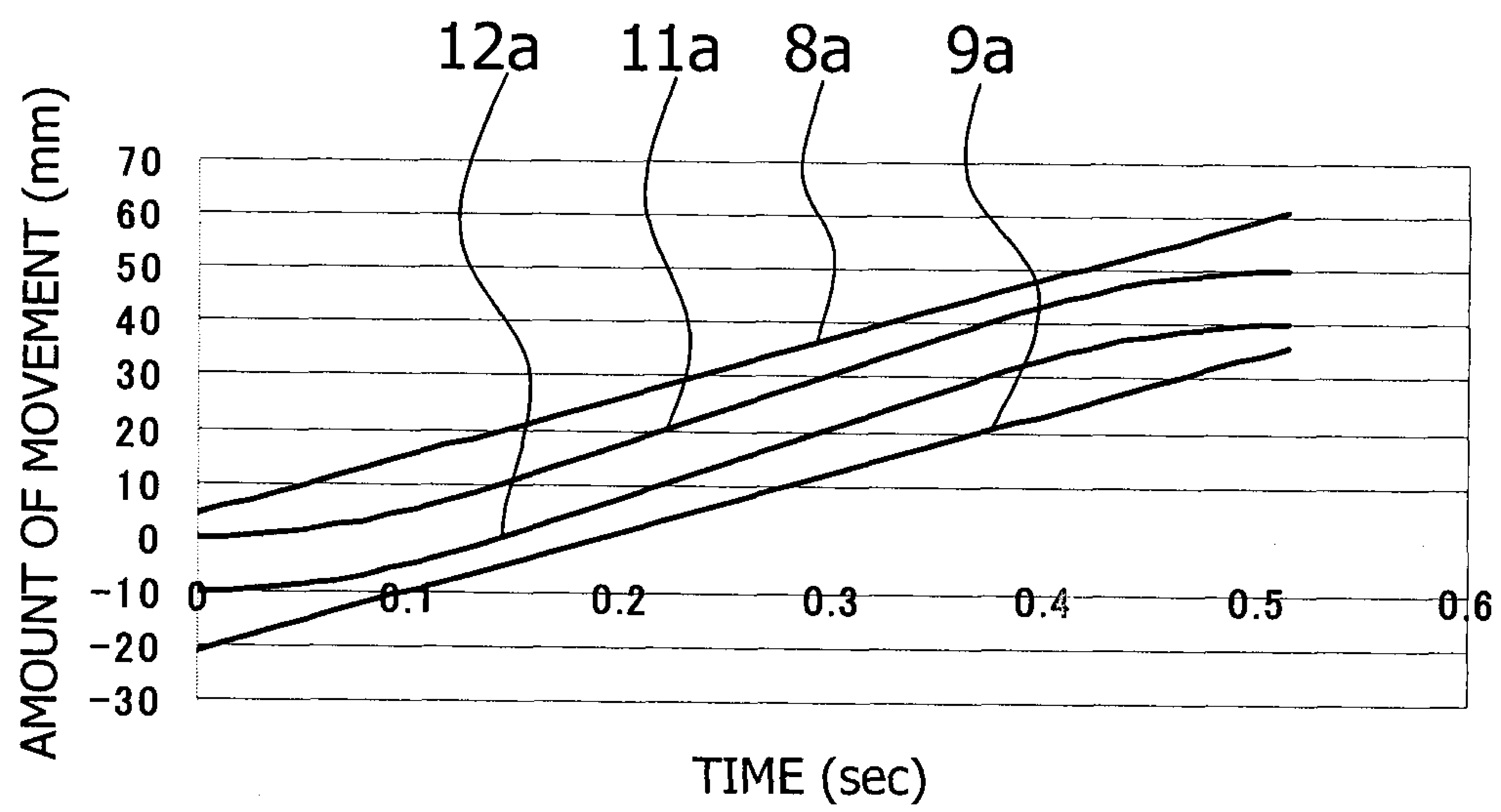


FIG.14

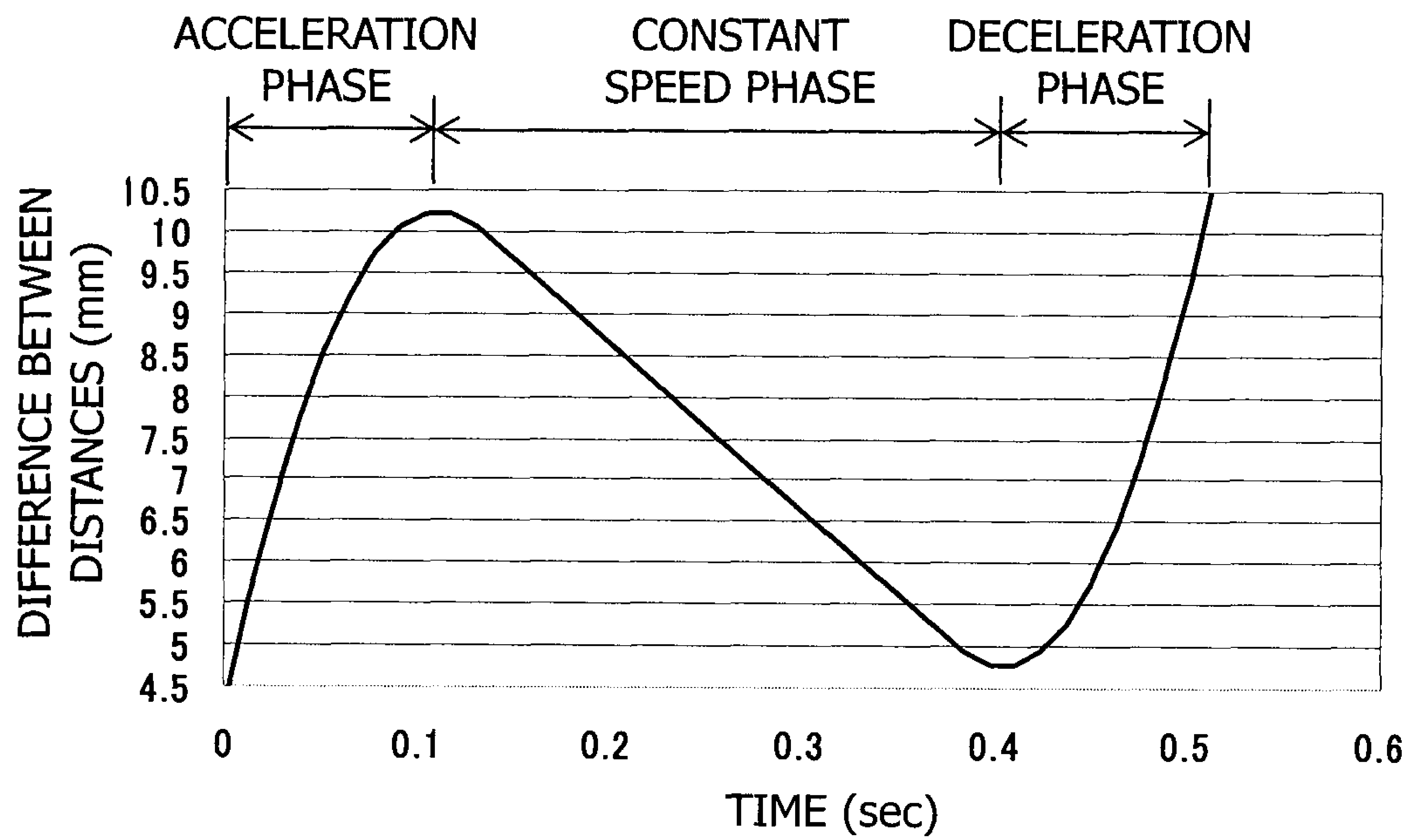


FIG.15

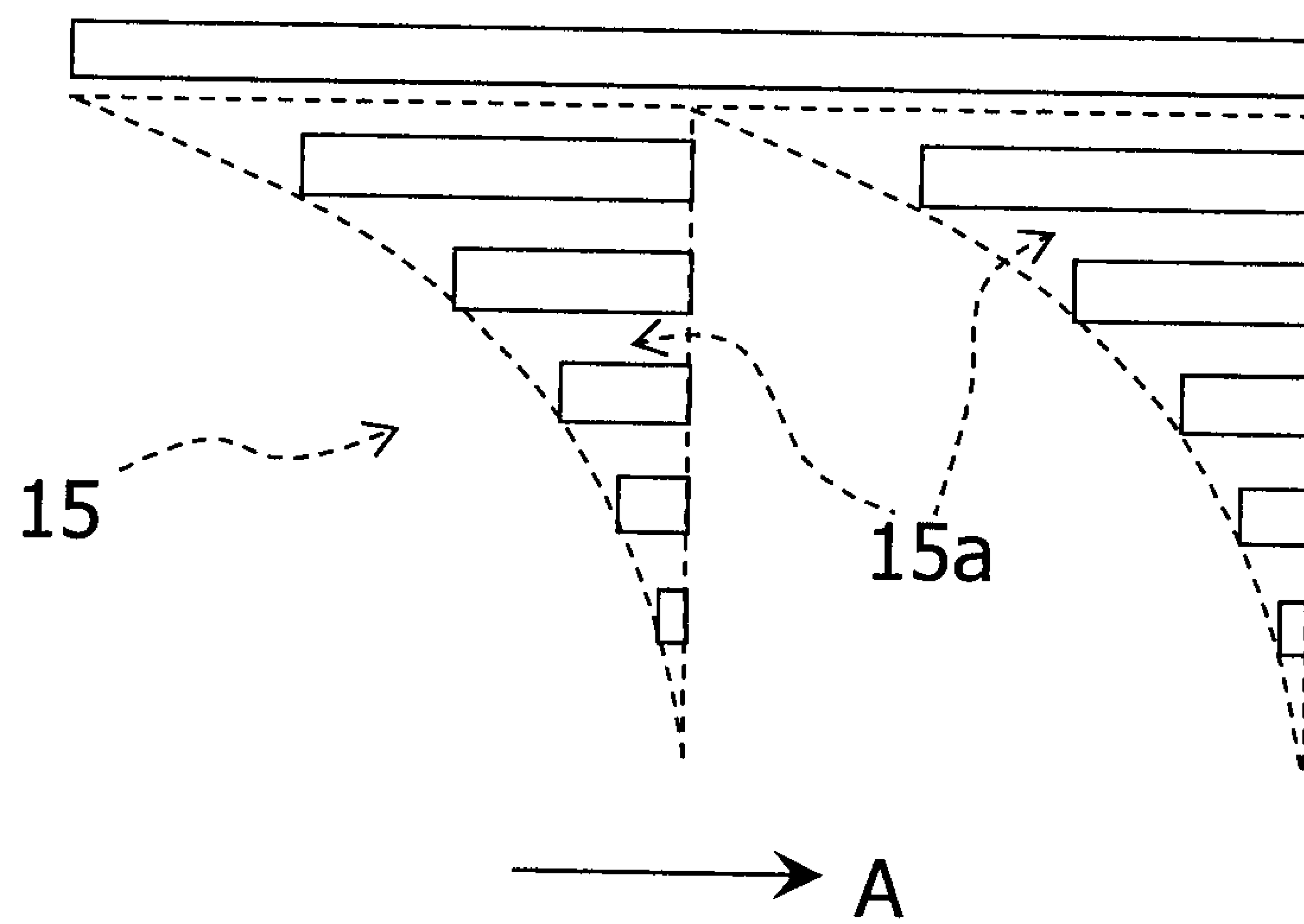


FIG.16A

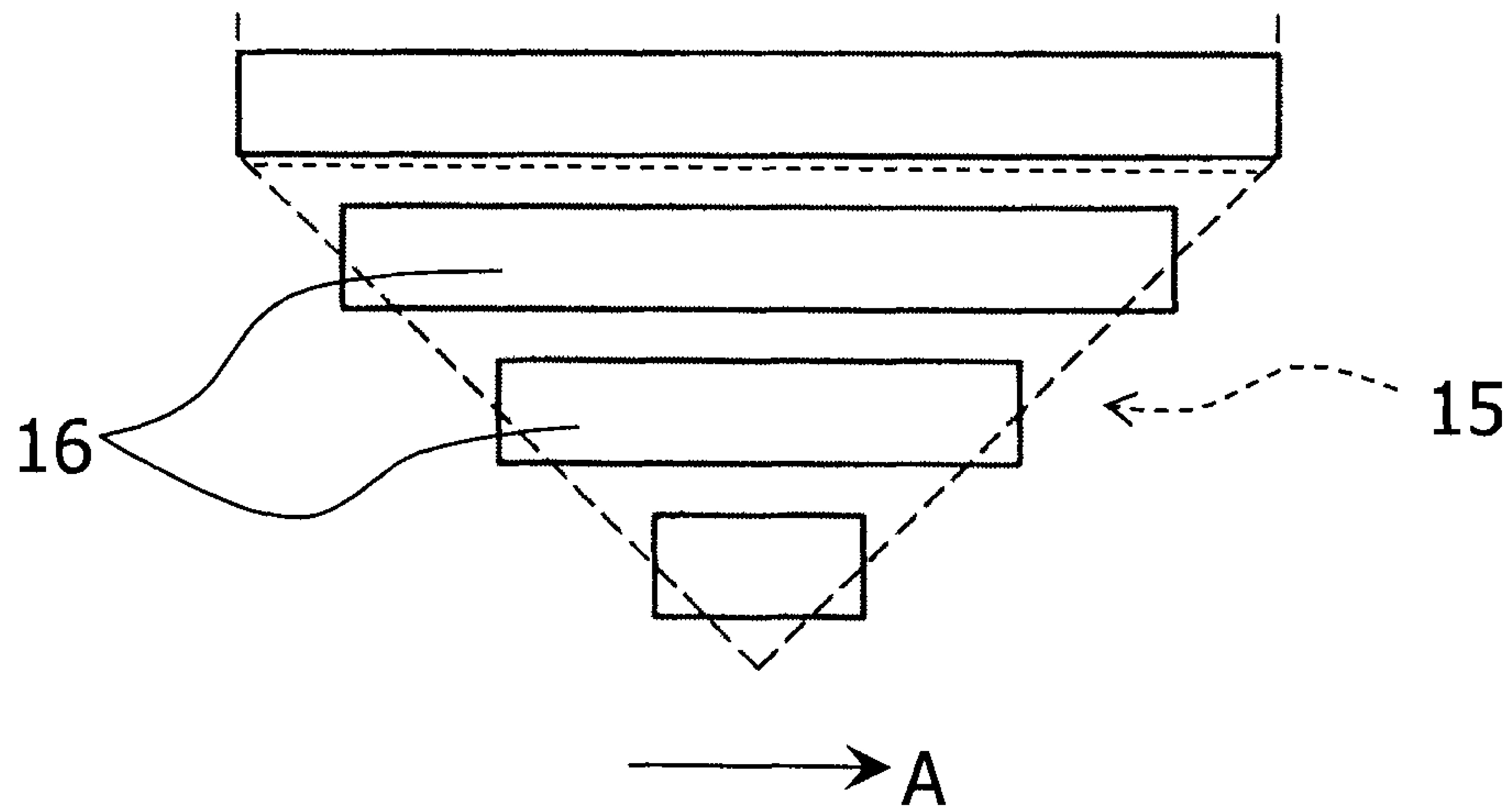
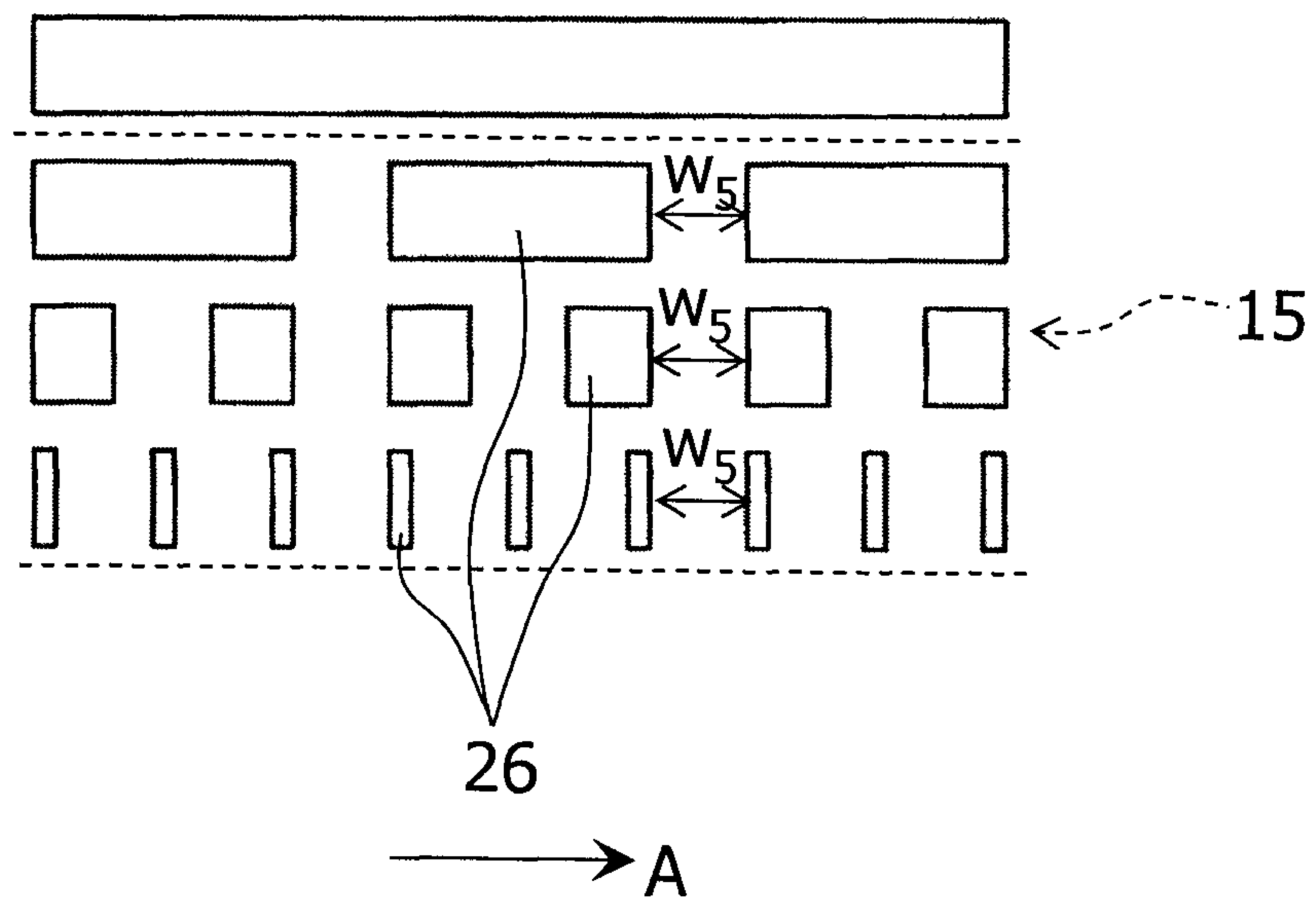


FIG.16B



EXPOSURE METHOD AND EXPOSURE APPARATUS

This application is a continuation of PCT/JP2010/071281, filed on Nov. 29, 2010.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an exposure method and an exposure apparatus for forming a different exposure pattern on each of a plurality of exposure areas arranged on an object to be exposed while conveying the object to be exposed at a constant speed in one direction, in particular, to an exposure method and an exposure apparatus for improving efficiency of forming a plurality of types of exposure patterns.

2. Description of Related Art

Conventionally, this type of exposure method is performed as follows. While conveying an object to be exposed in one direction, one mask pattern group of a photomask is selected and one exposure pattern group is formed by exposure on a predetermined exposure area on the object to be exposed by the one mask pattern group. Next, the object to be exposed is returned to a standby position, at which the object to be exposed is located before the exposure is started, and then the mask pattern group of the photomask is switched to another mask pattern group. Thereafter, the conveyance of the object to be exposed is restarted and another exposure pattern group is formed by exposure on another exposure area of the object to be exposed by the other mask pattern group (for example, refer to Japanese Laid-Open Patent Application No. 2008-310217).

However, in the conventional exposure method as described above, every time an exposure by one mask pattern group is completed, the object to be exposed is returned to the standby position, at which the object to be exposed is located before the exposure is started, so that the larger the number of types of exposure patterns to be formed, the longer the total moving distance of the object to be exposed until all exposures to the object to be exposed are completed. Therefore, there is a problem that forming exposure patterns is inefficient when forming a plurality of types of exposure patterns on the same object to be exposed.

SUMMARY OF THE INVENTION

Therefore, in view of the above conventional problems, an object of the present invention is to provide an exposure method and an exposure apparatus for improving the efficiency of forming a plurality of types of exposure patterns on the same object to be exposed.

In order to achieve the above object, the exposure method of the present invention is an exposure method for forming a different exposure pattern on each of a plurality of exposure areas arranged at predetermined intervals in a conveying direction of the object to be exposed while conveying the object to be exposed at a constant speed in one direction. The exposure method includes a step of moving a photomask by a predetermined distance and switching one mask pattern group to another mask pattern group when an exposure to one exposure area on the object to be exposed by the one mask pattern group of the photomask formed by arranging a plurality of types of mask pattern groups corresponding to the exposure patterns at predetermined intervals in the conveying direction of the object to be exposed is completed, and a step of performing an exposure on a next exposure area on the object to be exposed by the other mask pattern group. A moving speed of the photomask is controlled so that a moving distance of the object to be exposed is longer than a moving distance of the photomask in a period of time from when the photomask begins to move to switch the one mask pattern group to the other mask pattern group to when the photomask stops.

By the configuration as described above, while the object to be exposed is being conveyed at a constant speed in one direction, when an exposure to one exposure area on the object to be exposed by one mask pattern group of the photomask formed by arranging a plurality of types of mask pattern groups at predetermined intervals in the conveying direction of the object to be exposed is completed, the photomask is moved by a predetermined distance and the one mask pattern group is switched to another mask pattern group while controlling the moving speed of the photomask so that the moving distance of the object to be exposed is longer than the moving distance of the photomask, and an exposure on the next exposure area on the object to be exposed is performed by the other mask pattern group.

Preferably, the moving speed of the photomask is controlled to be switched to an acceleration phase in which the photomask is accelerated from a stopped state to a predetermined speed, a constant speed phase in which the photomask moves at the predetermined speed, and a deceleration phase in which the photomask decelerates and stops.

More preferably, the moving speed of the photomask in the constant speed phase is faster than a conveying speed of the object to be exposed.

The exposure apparatus of the present invention is an exposure apparatus for forming a different exposure pattern on each of a plurality of exposure areas arranged on an object to be exposed at predetermined intervals in a conveying direction of the object to be exposed while conveying the object to be exposed at a constant speed in one direction. The exposure apparatus includes a conveying device that conveys the object to be exposed at a predetermined speed, a mask stage which is provided to face an upper surface of the conveying device and which holds a photomask formed by arranging a plurality of types of mask pattern groups corresponding to the exposure patterns at predetermined intervals in a conveying direction of the object to be exposed and moves the photomask by a predetermined distance to switch one mask pattern group to another mask pattern group when an exposure to one exposure area on the object to be exposed by the one mask pattern group of the photomask is completed, and a control device that controls movement of the mask stage. The control device controls a moving speed of the mask stage so that a moving distance of the object to be exposed is longer than a moving distance of the photomask in a period of time from when the photomask begins to move to switch the one mask pattern group to the other mask pattern group to when the photomask stops.

By the configuration as described above, while the object to be exposed is being conveyed by the conveying device at a constant speed in one direction, when an exposure to one exposure area on the object to be exposed by one mask pattern group of the photomask formed by arranging a plurality of types of mask pattern groups at predetermined intervals in the conveying direction of the object to be exposed is completed, the photomask is moved by a predetermined distance and the one mask pattern group is switched to another mask pattern group while the control device controls the moving speed of the mask stage so that the moving distance of the object to be exposed is longer than the moving distance of the photomask, and an exposure on the next exposure area on the object to be exposed is performed by the other mask pattern group.

Preferably, the control device performs control to switch the moving speed of the mask stage to an acceleration phase in which the photomask is accelerated from a stopped state to a predetermined speed, a constant speed phase in which the photomask moves at the predetermined speed, and a deceleration phase in which the photomask decelerates and stops.

More preferably, the control device controls the moving speed of the mask stage in the constant speed phase to be faster than a conveying speed of the object to be exposed.

Furthermore, the photomask includes a first and a second photomasks, each of which includes a plurality of sets of the plurality of types of mask pattern groups which are aligned in a line at predetermined intervals, and the first and the second photomasks are shifted from each other by a predetermined distance in a direction substantially perpendicular to the conveying direction of the object to be exposed so that the plurality of sets of mask pattern groups are arranged in a direction substantially perpendicular to the conveying direction of the object to be exposed at a predetermined pitch in a staggered pattern.

Furthermore, in the same type of mask pattern groups of the plurality of types of mask pattern groups of the first and the second photomasks, mask patterns located in end regions of two mask pattern groups adjacent to each other as seen from the conveying direction of the object to be exposed overlap each other, and the mask patterns located in the end regions have shapes different from a shape of mask patterns located in a central portion of the mask pattern groups so that a predetermined amount of exposure can be obtained by a repeated exposure of the mask patterns corresponding to each other in the two mask pattern groups adjacent to each other.

Furthermore, the mask patterns located in an end region of the mask pattern groups of the first and the second photomasks are divided into a plurality of portions at predetermined pitches in a direction substantially perpendicular to the conveying direction of the object to be exposed.

Moreover, the mask patterns located in an end region of the mask pattern groups of the first and the second photomasks are divided into a plurality of small patterns at predetermined intervals in a direction substantially perpendicular to the conveying direction of the object to be exposed and sizes of the small patterns are set so that a sum of areas of the plurality of small patterns is a predetermined value.

According to a first aspect and a fourth aspect of the invention, which is different from the conventional technique, it is possible to form a different exposure pattern on each of a plurality of exposure areas while continuously moving the object to be exposed at a predetermined speed without returning the object to be exposed to a standby position, at which the object to be exposed is located before exposure is started, every time an exposure to a predetermined exposure area is completed. Therefore, the total moving distance of the object to be exposed until all exposures are completed is significantly shorter than that in the conventional technique. Therefore, it is possible to improve forming efficiency of a plurality of types of exposure patterns on the same object to be exposed compared with the conventional technique. The moving speed of the photomask is controlled so that the moving distance of the object to be exposed is longer than the moving distance of the photomask in a period of time from when the photomask begins to move to switch one mask pattern group to another mask pattern group to when the photomask stops. Thus, in a case in which, for example, a repeated exposure is performed by end regions of mask pattern groups arranged along the conveying direction of the object to be exposed, when the shapes of the mask patterns located in the end regions are changed from the shape of mask patterns located in a central portion of the mask pattern groups to avoid an over exposure by the repeated exposure of the end regions, it is possible to solve the problem that unexposed portions are generated corresponding to the end regions.

Furthermore, according to a second aspect and a fifth aspect of the invention, it is possible to prevent the unexposed portions from being generated even when a distance between a plurality of exposure areas in the conveying direction of the object to be exposed is smaller than a distance between the longitudinal center axes of a plurality of types of mask pattern groups of the photomask.

Furthermore, according to a third aspect and a sixth aspect of the invention, it is possible to expose the entire exposure areas by substantially the same amount of exposure while avoiding a still exposure state.

Furthermore, according to a seventh aspect of the invention, it is possible to form exposure patterns in a dense state.

Furthermore, according to an eight aspect of the invention, it is possible to prevent that the exposure area corresponding to the end regions is over exposed when the repeated exposure is performed by the end regions of the mask pattern groups arranged along the conveying direction of the object to be exposed.

Furthermore, according to a ninth aspect of the invention, it is possible to uniformize the exposure performed by the end regions of the mask pattern groups.

Then, according to a tenth aspect of the invention, it is possible to further uniformize the exposure performed by the end regions of the mask pattern groups.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic view showing an embodiment of an exposure apparatus according to the present invention;

FIG. **2** is a plan view showing an arrangement example of a plurality of exposure areas arranged on a surface of an object to be exposed which is used in the exposure apparatus;

FIG. **3** is a plan view showing a configuration example of a photomask used in the exposure apparatus;

FIG. **4** is a plan view showing a shape example of a mask pattern located at an end region of a mask pattern group of the photomask;

FIGS. **5**A and **5**B are views showing exposure in which the photomask is moved at the same speed as that of the object to be exposed while the mask pattern group is switched when a distance between a first exposure area and a second exposure area of the object to be exposed is the same as a distance between the longitudinal center axes of a first and a second mask pattern groups of the photomask;

FIGS. **6**A and **6**B are views showing exposure in which the photomask is moved at a speed slower than that of the object to be exposed while the mask pattern group is switched when the distance between the first exposure area and the second exposure area of the object to be exposed is larger than the distance between the longitudinal center axes of the first and the second mask pattern groups of the photomask;

FIGS. **7**A and **7**B are views showing exposure in which the photomask is moved at the same speed as that of the object to be exposed while the mask pattern group is switched when the distance between the first exposure area and the second exposure area of the object to be exposed is smaller than the distance between the longitudinal center axes of the first and the second mask pattern groups of the photomask;

FIG. **8** is a plan view showing shapes of the first and the second mask pattern groups of the photomask according to the embodiment of the present invention;

FIG. **9** is a block diagram showing a schematic configuration of a control device of the exposure apparatus;

FIG. **10** is a flowchart showing an exposure method of the present invention;

FIG. **11**A to **11**D are views showing an exposure method of the present invention;

FIG. **12** is a view showing an example of a control profile of movement of a mask stage according to the present invention;

FIG. **13** is a graph showing a relationship between an amount of movement of the object to be exposed and an amount of movement of the photomask according to another control example of the present invention;

FIG. **14** is a graph showing variation of difference between the moving distances of the object to be exposed and the photomask in the control of FIG. **13**;

FIG. **15** is a plan view showing another shape example of small units formed by dividing an end region of the photomask into a plurality of small units; and

FIGS. **16**A and **16**B are plan views showing another shape example of a mask pattern located at an end region of a mask pattern group of the photomask.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, an embodiment of the present invention will be described in detail with reference to the attached drawings. FIG. **1** is a schematic view showing an embodiment of an exposure apparatus according to the present invention. The exposure apparatus forms a different exposure pattern on each of a plurality of exposure areas arranged on an object to be exposed while conveying the object to be exposed at a constant speed in one direction in a process of performing exposure. The exposure apparatus includes a conveying device **1**, a light source **2**, a coupling optical system **3**, a mask stage **4**, an imaging device **5**, and a control device **6**.

An object to be exposed **7** is placed on an upper surface **1***a* of the conveying device **1** and the conveying device **1** conveys the object to be exposed **7** in a direction indicated by an arrow A at a constant speed V_G. The conveying device **1** ejects and draws gas through the upper surface **1***a* and conveys the object to be exposed **7** while floating the object to be exposed **7** by a predetermined distance by balancing the ejecting force and the drawing force of the gas. The conveying device **1** is equipped with a speed sensor (not shown in the drawings) for detecting the moving speed V_G of the object to be exposed **7** and a position sensor (not shown in the drawings) for detecting the position of the object to be exposed **7**.

As shown in FIG. **2**, a first exposure area **8** on which a first exposure pattern group will be formed and a second exposure area **9** on which a second exposure pattern group will be formed are arranged in advance on the object to be exposed **7** used here with a distance W_1 in between in the conveying direction (direction indicated by the arrow A). The object to be exposed **7** is a color filter substrate or the like in which, for example, a plurality of display panels having different sizes are attached to one large glass substrate.

The light source **2** is provided above the conveying device **1**. The light source **2** irradiates ultraviolet rays. The light source **2** is a xenon lamp, an extra high pressure mercury lamp, a laser, or the like.

The coupling optical system **3** is provided in front of the light source **2** in a direction in which the light is irradiated. The coupling optical system **3** converts the light irradiated from the light source **2** into parallel light and irradiates the parallel light to a mask pattern group of a photomask **10** described later. The coupling optical system **3** includes optical components such as a photo integrator and a condenser lens. The coupling optical system **3** further includes a mask for shaping a cross-sectional shape of the light according to an outer shape of a forming area of each mask pattern group of the photomask **10**.

The mask stage **4** is provided to face the upper surface of the conveying device **1**. The mask stage **4** holds a marginal edge portion of the photomask **10** formed by arranging a first and a second mask pattern groups **11** and **12** (see FIG. **3**) that respectively corresponds to different types of the first and the second exposure pattern groups formed on the object to be exposed **7** with a distance W_2 (see FIG. **3**) smaller than the distance W_1 between the first and the second exposure areas **8** and **9** arranged on the object to be exposed **7**, in between in the conveying direction of the object to be exposed **7** (direction indicated by the arrow A).

When an exposure that is performed on the first exposure area **8** on the object to be exposed **7** by using the mask pattern group **11** of the photomask **10** is completed, the mask stage **4** switches the first mask pattern group **11** to the second mask pattern group **12** by moving the photomask **10** in the same direction (indicated by an arrow B) as the conveying direction of the object to be exposed **7** (direction indicated by the arrow A) by a distance corresponding to a distance W_3 (see FIG. **3**) between the longitudinal center axes of the first and the second mask pattern groups **11** and **12**. The mask stage **4** is equipped with a speed sensor and a position sensor not shown in the drawings.

Here, as shown in FIG. **3**, the photomask **10** includes a first and a second photomasks **13** and **14** each of which includes a plurality of pairs of the first and the second mask pattern groups **11** and **12** which are aligned in a line at predetermined intervals. The first and the second photomasks **13** and **14** are shifted from each other by a predetermined distance in a direction substantially perpendicular to the conveying direction of the object to be exposed **7** (direction indicated by the arrow A) so that the plurality of pairs of the first and the second mask pattern groups **11** and **12** are arranged in a direction substantially perpendicular to the conveying direction of the object to be exposed **7** (direction indicated by the arrow A) at a predetermined pitch in a staggered pattern.

In this case, in the same type of mask pattern groups of the two types of mask pattern groups **11** and **12** of the first and the second photomasks **13** and **14**, for example, in the first mask pattern groups **11**, an end region (a portion sandwiched by two dashed lines in FIG. **3**) **15** of one first mask pattern group **11** overlaps an end region **15** of a first mask pattern group **11** adjacent to the first mask pattern group **11** as seen from the conveying direction of the object to be exposed **7** (direction indicated by the arrow A) and positions of mask patterns **16** (see FIG. **4**) in the two end regions **15** correspond to each other in the direction indicated by the arrow A. The mask patterns **16** located in the end region **15** have shapes different from the shape of the mask patterns **16** located in the central portion of the first mask pattern group **11** so that a predetermined amount of exposure can be obtained by a repeated exposure of the mask patterns **16** corresponding to each other of two first mask pattern groups **11** adjacent to each other.

In particular, as shown in FIG. **4**, the mask patterns **16** are formed an elongated rectangular shape in the direction indicated by the arrow A so that a length along the long axis of the mask pattern **16** located in the triangle-shaped end region **15** becomes progressively shorter as the position of the mask pattern **16** along the longitudinal center axis of the first mask pattern group **11** becomes closer to the outside. A sum of opening areas of two mask patterns **16***a* and **16***b* correspond-

ing to each other located in the end regions **15** of two first mask pattern groups **11** adjacent to each other in the direction indicated by the arrow A is substantially the same as an opening area of a mask pattern **16***c* located in the central portion of the first mask pattern group **11**. Thereby, the amount of repeated exposure by the two mask patterns **16***a* and **16***b* aligned in the direction indicated by the arrow A in the end regions **15** of the first mask pattern groups **11** is substantially the same as the amount of exposure by the mask pattern **16***c* in the central portion of the first mask pattern group **11**, so that over exposure is avoided.

To form different exposure patterns on two exposure areas on the object to be exposed **7** by using the photomask **10** described above, when the exposure to the first exposure area **8** on the object to be exposed **7** by the first mask pattern group **11** is completed, the photomask **10** is moved by the distance W_3 in the same direction (direction indicated by the arrow B) as the conveying direction of the object to be exposed **7** (direction indicated by the arrow A) to switch the first mask pattern group **11** to the second mask pattern group **12**, and then the exposure to the second exposure area **9** on the object to be exposed **7** is performed by the second mask pattern group **12**.

In this case, when the distance W_1 between the first exposure area **8** and the second exposure area **9** is larger than or equal to the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12** of the photomask **10**, the photomask **10** may be moved at a speed slower than or equal to the moving speed V_G of the object to be exposed **7** while the first mask pattern group **11** is switched to the second mask pattern group **12**.

FIG. **5** is a view showing the exposure in which the photomask **10** is moved at a moving speed V_M that is the same as the moving speed V_G of the object to be exposed **7** when the distance W_1 between the first exposure area **8** and the second exposure area **9** of the object to be exposed **7** is the same as the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12** of the photomask **10**. According to FIG. **5**, when a rear end portion **8***a* located upstream in the direction indicated by the arrow A of the first exposure area **8** on the object to be exposed **7** corresponds to the longitudinal center axis of the first mask pattern group **11** of the photomask **10** (see FIG. **5**A. At this time, a front end portion **9***a* located downstream in the direction indicated by the arrow A of the second exposure area **9** corresponds to the longitudinal center axis of the second mask pattern group **12**), if the photomask **10** begins to be moved in the direction indicated by the arrow B to switch the mask pattern group (see FIG. **5**B), an exposure can be performed on the entire area of the first exposure area **8** by the first mask pattern group **11** and an exposure can be performed on the entire area of the second exposure area **9** by the second exposure pattern group.

FIG. **6** is a view showing the exposure in which the photomask **10** is moved at a moving speed V_M that is slower than the moving speed V_G of the object to be exposed **7** when the distance W_1 between the first exposure area **8** and the second exposure area **9** of the object to be exposed **7** is larger than the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12** of the photomask **10**. According to FIG. **6**, when the rear end portion **8***a* in the direction indicated by the arrow A of the first exposure area **8** on the object to be exposed **7** corresponds to the longitudinal center axis of the first mask pattern group **11** of the photomask **10** (see FIG. **6**A), if the photomask **10** begins to be moved in the direction indicated by the arrow B to switch the mask pattern group (see FIG. **6**B), it is possible to cause the front end portion **9***a* in the direction indicated by the arrow A of the second exposure area **9** of the object to be exposed **7** to correspond to the longitudinal center axis of the second mask pattern group **12** of the photomask **10** when or after the switching is completed. Therefore, also in this case, an exposure can be performed on the entire area of the first exposure area **8** by the first mask pattern group **11** and an exposure can be performed on the entire area of the second exposure area **9** by the second mask pattern group **12**.

However, as shown by the object to be exposed **7** of the present embodiment shown in FIGS. **7**A and **7**B, when the distance W_1 between the first exposure area **8** and the second exposure area **9** is smaller than the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12** of the photomask **10**, as shown in FIGS. **7**A and **7**B, if the photomask **10** is moved at a moving speed V_M that is the same as the moving speed V_G of the object to be exposed **7** while switching the mask pattern group, an unexposed portion **17** is generated in a part of the rear end portion **8***a* in the direction indicated by the arrow A of the first exposure area **8** or the front end portion **9***a* of the second exposure area **9**. When the photomask **10** is moved at a moving speed V_M slower than the moving speed V_G of the object to be exposed **7** while the first mask pattern group **11** is switched to the second mask pattern group **12**, the front end portion **9***a* in the direction indicated by the arrow A of the second exposure area **9** goes beyond the longitudinal center axis of the second mask pattern group **12** before the first mask pattern group **11** is switched to the second mask pattern group **12**, so that an unexposed portion **17** is generated in a part of the front end portion **9***a* of the second exposure area **9**.

Therefore, in the present embodiment, as shown in FIG. **8**, an end region **15** which overlaps the adjacent mask pattern group in the direction indicated by the arrow A in the same type of mask pattern group is divided into a plurality of portions (divided into 10 portions in FIG. **8**) at a pitch W_4 in a direction substantially perpendicular to the direction indicated by the arrow A, and each small unit **15***a* formed by dividing the end region **15** is shaped into a triangle. At the same time, the moving speed V_M of the mask pattern **16** is switched to an acceleration phase in which the moving speed is accelerated from a stopped state to a predetermined speed (which is the same speed as the moving speed V_G of the object to be exposed **7** in the present embodiment), a constant speed phase in which the mask pattern **16** is moved at the predetermined speed, and a deceleration phase in which the mask pattern decelerates and stops. In the acceleration phase and the deceleration phase, the photomask **10** is moved by at least the same distance as the division size W_4 of the end region **15** of the mask pattern groups **11** and **12**. Thereby, even when the distance W_1 between the first exposure area **8** and the second exposure area **9** is smaller than the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12**, an exposure can be performed on the entire area of the first exposure area **8** by the first mask pattern group **11** and an exposure can be performed on the entire area of the second exposure area **9** by the second exposure pattern group without generating an unexposed portion **17** (see FIG. **11**A to **11**D).

The imaging device **5** is provided to capture an image of a position upstream of an exposure area of the photomask **10** in the conveying direction. The imaging device **5** captures an image of the surface of the object to be exposed **7**. The imaging device **5** is a line camera in which a plurality of light receiving elements are aligned in a line in a direction substantially perpendicular to the conveying direction (indicated by the arrow A) in a plane parallel with the upper surface **1***a* of

the conveying device **1**. A distance between an imaging center of the imaging device **5** and a rear end located upstream in the direction indicated by the arrow A of an exposure light irradiation area of the photomask **10** when the mask stage **4** is in a stopped state is set to a distance L.

The control device **6** is provided and electrically connected to the conveying device **1**, the light source **2**, the mask stage **4**, and the imaging device **5**. The control device **6** controls the moving speed V_M of the mask stage **4** so that a moving distance of the object to be exposed **7** is longer than a moving distance of the photomask **10** in a period of time from when the photomask **10** begins to move to switch the first mask pattern group **11** to the second mask pattern group **12** to when the photomask **10** stops. As shown in FIG. **9**, the control device **6** includes an image processing unit **18**, a memory **19**, a calculation unit **20**, a conveying device drive controller **21**, a mask stage drive controller **22**, a light source drive controller **23**, and a control unit **24**.

The image processing unit **18** processes an image of the surface of the object to be exposed **7**, which is captured by the imaging device **5**, and detects a front position located downstream of each exposure area in the conveying direction. The memory **19** stores lengths D_1 and D_2 of each exposure area in the direction indicated by the arrow A, the distance L between the imaging center of the imaging device **5** and the rear end located upstream of the exposure light irradiation area of the photomask **10** in the direction indicated by the arrow A, and a control profile of the moving speed V_G of the object to be exposed **7** and the moving speed V_M of the mask stage **4**, and temporarily stores a calculation result of the calculation unit **20** described later. Furthermore, the calculation unit **20** calculates a moving distance of the object to be exposed **7** on the basis of an output of the position sensor of the conveying device **1** and calculates a moving distance of the photomask **10** on the basis of an output of the position sensor of the mask stage **4**. The conveying device drive controller **21** controls the stage of the conveying device **1** to move at a constant speed V_G. The mask stage drive controller **22** controls the movement of the mask stage **4** on the basis of the control profile stored in the memory **19**. The light source drive controller **23** controls drive for turning on and off the light source **2**. The control unit **24** integrally controls the above components so that each component operates properly.

Next, the operation of the exposure apparatus configured as described above will be described with reference to FIG. **10**.

First, in step S**1**, the mask stage **4** stops and the first mask pattern group **11** of the photomask **10** is selected.

In step **2**, the conveying device drive controller **21** controls the conveying device **1** to begin to move and the conveying device **1** conveys the object to be exposed **7** at a constant speed V_G in the direction indicated by the arrow A.

In step S**3**, the image processing unit **18** processes an image of the surface of the object to be exposed **7**, which is captured by the imaging device **5**, and detects an front edge located downstream in the direction indicated by the arrow A of, for example, a reference pattern such as pixels formed in the first exposure area **8** in advance in the front end portion located downstream of the first exposure area **8** in the direction indicated by the arrow A.

In step S**4**, the calculation unit **20** calculates a distance which the object to be exposed **7** moves from when the front end portion located downstream of the first exposure area **8** in the direction indicated by the arrow A is detected on the basis of the output of the position sensor of the conveying device **1**. If the moving distance of the object to be exposed **7** corresponds to the distance L read from the memory **19** and "YES" is determined in step S**4**, the process proceeds to step S**5**.

In step S**5**, the light source drive controller **23** starts and turns on the light source **2**. Thereby, the first mask pattern group **11** of the photomask **10** is irradiated with light irradiated from the light source **2** and converted into parallel light through the coupling optical system **3**, and having the cross-sectional shape of which is formed into a rectangular shape according to the outer shape of the mask pattern group. Thereby, an image of a pattern corresponding to the first mask pattern group **11** of the photomask **10** is exposed to the first exposure area **8** of the object to be exposed **7** and a first exposure pattern is formed. At this time, a repeated exposure is performed by the end region **15** of the first mask pattern group **11** of the second photomask **14** by tracing exposure paths of the end region **15** of the first mask pattern group **11** of the first photomask **13**, and an exposure of a predetermined depth is performed.

In step S**6**, the moving distance of the object to be exposed **7** is calculated by the calculation unit **20** on the basis of the output of the position sensor of the conveying device **1** and it is determined whether or not the moving distance corresponds to the length D_1 in the direction indicated by the arrow A of the first exposure area **8** read from the memory **19** and the exposure to the first exposure area **8** is completed. Here, if the distance and the length correspond to each other and "YES" is determined in step S**6**, the process proceeds to step S**7**. In the present embodiment, as shown in FIG. **11**A, when the object to be exposed **7** moves a distance (D_1+W_4) (W_4 is the division size of the first mask pattern group **11**), it is determined that the exposure to the first exposure area **8** is completed.

In step S**7**, the mask stage drive controller **22** starts, controls the movement of the mask stage **4** according to the control profile shown in FIG. **12**, and switches the first mask pattern group **11** to the second mask pattern group **12**.

Hereinafter, the exposure method of the present invention will be described with reference to FIGS. **11** and **12**.

First, as shown in FIG. **11**A, when the exposure to the first exposure area **8** by the first mask pattern group **11** is completed, the mask stage **4** begins to move in the direction indicated by the arrow B. At this time, as shown in FIG. **12**, the moving speed of the mask stage **4** is accelerated to the same speed as the moving speed V_G of the object to be exposed **7** after a time t_1 elapses. Therefore, the moving distance of the photomask **10**, which moves in the acceleration phase, is $(V_G \cdot t_1/2)$, which is a half of the moving distance (V_G-t_1) of the object to be exposed **7**. Therefore, if the acceleration time t_1 is set in advance so that the moving distance of the photomask **10** in the acceleration phase is W_4 as shown in FIG. **11**B, the object to be exposed **7** further advances by $2W_4$ when the acceleration is completed as shown in FIG. **11**B. Thereby, the first exposure area **8** corresponding to the end region **15** of the first mask pattern group **11** is uniformly exposed without generating an unexposed portion **17**.

When the acceleration phase is completed, the mask stage **4** proceeds to the constant speed phase as shown in FIG. **12**. At this time, the mask stage **4** moves at the same speed as the moving speed V_G of the object to be exposed **7**. Here, if a time (t_2-t_1) is set in advance so that the moving distance of the mask stage **4** in the constant speed phase is, for example, (W_2+8W_4), as shown in FIG. **11**C, the photomask **10** moves at the same speed as the moving speed V_G of the object to be exposed **7** until a front end portion **12***a* located downstream in the direction indicated by the arrow A of the second mask pattern group **12** of the photomask **10** reaches a position a distance W_4 upstream of a front end portion **25***a* located downstream in the direction indicated by the arrow A of a light irradiation area **25**. Therefore, the exposure in the con-

stant speed phase is the same as a still exposure, so that, as shown in FIG. **11**C, the shape of the second mask pattern group **12** is transferred to the second exposure area **9** and unexposed portions **17** are generated corresponding to the end regions **15** of the second mask pattern group **12**.

When the constant speed phase is completed, the mask stage **4** proceeds to the deceleration phase as shown in FIG. **12** and the mask stage **4** gradually decreases the speed and stops after a time (t_3-t_2) elapses. At this time, if (t_3-t_2) is set to t_1, as shown in FIG. **11**D, the mask stage **4** stops after advancing by the distance W_4 in the deceleration phase. On the other hand, during the deceleration phase, the object to be exposed **7** moves a distance $2W_4$, which is two times the moving distance of the mask stage **4**, so that, as shown in FIG. **11**D, the unexposed portions **17** of the second exposure area **9** are exposed by the end regions **15** of the second mask pattern group **12**.

As describe above, the distance which the mask stage **4** moves from when the mask stage **4** begins to move to when the mask stage **4** stops corresponds to the area of the trapezoid abcd in FIG. **12**, so that the distance is $V_G \cdot t_2$. In FIG. **11**A to **11**D, the distance is (W_2+10W_4), which is the same as the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12**, so that the switching of the mask pattern groups is appropriately performed.

On the other hand, the distance which the object to be exposed **7** moves from when the mask stage **4** begins to move to when the mask stage **4** stops corresponds to the area of the rectangle aefd in FIG. **12**, so that the distance is $V_G \cdot t_3$. In FIGS. **11**A and **11**B, the distance is (W_2+12W_4), which is longer than the moving distance of the mask stage **4**.

In this way, when the exposure to the first exposure area **8** on the object to be exposed **7** by the mask pattern group **11** of the photomask **10** is completed and the first mask pattern group **11** is switched to the second mask pattern group **12**, the moving speed of the photomask **10** is controlled so that the moving distance of the object to be exposed **7** is longer than the moving distance of the photomask **10**. Thus, it is possible to prevent the unexposed portions **17** from being generated corresponding to the end regions **15** of the first and the second mask pattern groups **11** and **12** of the photomask **10**. In particular, the movement of the photomask **10** is controlled according to the control profile of acceleration, constant speed, and deceleration, so that, even when the distance W_1 between the first and the second exposure areas **8** and **9** of the object to be exposed **7** is smaller than the distance W_3 between the longitudinal center axes of the first and the second mask pattern groups **11** and **12** of the photomask **10**, it is possible to prevent the unexposed portions **17** from being generated in portions of the exposure area corresponding to the end regions **15** of the mask pattern groups.

When the switching of the mask pattern groups of the photomask **10** is completed in this way, the process proceeds to step S**8** and an exposure is performed on the second exposure area **9** on the object to be exposed **7** by the second mask pattern group **12** of the photomask **10**.

In step S**9**, the moving distance of the object to be exposed **7** is calculated by the calculation unit **20** on the basis of the output of the position sensor of the conveying device **1** and it is determined whether or not the moving distance corresponds to the length D_2 in the direction indicated by the arrow A of the second exposure area **9** read from the memory **19** and the exposure to the second exposure area **9** is completed. Here, if the distance and the length correspond to each other and "YES" is determined, the exposure is completed. Then, the light source **2** is controlled to be turned off by the light source drive controller **23** and the drive of the conveying device **1** is controlled to be stopped by the conveying device drive controller **21**. Here, when a plurality of objects to be exposed **7** are sequentially conveyed and exposure is continuously performed on the plurality of objects to be exposed **7**, the conveying device **1** is continuously driven.

Although, in the present embodiment, a case is described in which the moving speed V_M of the photomask **10** at the constant speed is set to be the same as the moving speed V_G of the object to be exposed **7**, the present invention is not limited to this, and the moving speed V_M of the photomask **10** at the constant speed may be set to be faster than the moving speed V_G of the object to be exposed **7**.

FIG. **13** is a graph showing a relationship between the amount of movement of the object to be exposed **7** and the amount of movement of the photomask **10** according to another control example of the present invention.

FIG. **13** is a graph calculated by assuming that the photomask **10** shown in FIG. **8** is used, the acceleration of the photomask **10** is 1000 mm/sec^2, the moving speed V_M of the photomask **10** at the constant speed is 130 mm/sec, the moving distance of the photomask **10** is 50 mm, and the moving speed V_G of the object to be exposed **7** is 110 mm/sec. In this case, the distance W_1 between the first exposure area **8** and the second exposure area **9** of the object to be exposed **7** is 25 mm and the width in the direction indicated by the arrow A of the first and the second mask pattern groups **11** and **12** of the photomask **10** is 40 mm. Immediately before the photomask **10** begins to move, the rear end portion **8**_a_ in the direction indicated by the arrow A of the first exposure area **8** on the object to be exposed **7** advances in the direction indicated by the arrow A 4.2 mm farther than the rear end portion **11**_a_ in the direction indicated by the arrow A of the first mask pattern group **11** of the photomask **10**.

As a result, while the photomask **10** moves 50 mm and the first mask pattern group **11** is switched to the second mask pattern group **12**, the distance which the object to be exposed **7** moves is 56.6 mm. The moving speed V_M of the photomask **10** at the constant speed is set to be faster than the moving speed V_G of the object to be exposed **7**, so that a difference between the moving distances of the photomask **10** and the object to be exposed **7** while the photomask **10** is moving varies as shown in FIG. **14**. Therefore, it is possible to prevent the occurrence of the same exposure state as that of the still exposure during the constant speed phase of the moving of the photomask **10** as described in the above embodiment. Thereby, the over exposure in the constant speed phase can be avoided and a uniform exposure can be performed by a substantially uniform amount of exposure over the entire exposure area.

Although, in the above embodiment, a case is described in which the end region **15** of the mask pattern group is divided into 10 portions, the present invention is not limited to this, and the mask pattern group can be divided into any number of portions. In particular, the larger the number of divided portions, the more uniformly the exposure can be performed.

In this case, the shape of each small unit **15**_a_ obtained by dividing the end region **15** into a plurality of portions is not limited to an isosceles triangle shown in FIG. **8**, but the shape may be a right triangle in which the downstream side in a substrate conveying direction (direction indicated by the arrow A) is perpendicular to the direction indicated by the arrow A as shown in FIG. **15** or, as shown in FIG. **15**, the side opposing the downstream side in the substrate conveying direction in the direction indicated by the arrow A may be a hyperbolic curve.

Furthermore, although, in the above embodiment, a case is described in which the end region **15** of the mask pattern group is a triangle, the present invention is not limited to this, and for example, as shown in FIGS. **16**A and **16**B, the mask patterns **16** may be divided into a plurality of small patterns **26** (see FIG. **16**B) with a distance W_5 in between in a direction substantially perpendicular to the conveying direction of the object to be exposed **7** so that the total area of the divided mask patterns **16** is the same as the opening areas of the mask patterns **16** (see FIG. **16**A) in the end region **15**. In this case, if the distance W_5 is reduced to a length smaller than the resolution power (for example, about 1 μm), the exposure can be performed more uniformly.

Although, in the above embodiment, a case is described in which there are two exposure areas arranged on the object to be exposed **7**, the present invention is not limited to this, and there may be three or more exposure areas arranged on the object to be exposed **7**. In this case, three or more mask pattern groups are provided on the photomask **10**. When step **S9** described above is completed, the process returns to step S**7**, and steps S**7** to S**9** are repeatedly performed until the exposure to all the exposure areas is completed.

Although, in the present embodiment, a case is described in which the present invention is applied to a proximity exposure apparatus in which the photomask **10** is arranged to be opposite to and close to the object to be exposed **7**, the present invention is not limited to this, but may be applied to a projection exposure apparatus in which the mask pattern group of the photomask **10** is projected and exposed onto the object to be exposed **7**. In this case, the moving direction of the photomask **10** is opposite to the conveying direction of the object to be exposed **7**.

It should be noted that the entire contents of Japanese Patent Application No. 2009-283067, filed on Dec. 14, 2009, on which the convention priority is claimed is incorporated herein by reference.

It should also be understood that many modifications and variations of the described embodiments of the invention will occur to a person having an ordinary skill in the art without departing from the spirit and scope of the present invention as claimed in the appended claims.

What is claimed is:

1. An exposure method for forming a different exposure pattern on each of a plurality of exposure areas arranged at predetermined intervals in a conveying direction of an object to be exposed while conveying the object at a constant conveying speed in one direction, the exposure method comprising:

a step of moving a photomask by a predetermined distance in the same direction as the conveying direction of the object and switching one mask pattern group to another mask pattern group when an exposure to one exposure area on the object by the one mask pattern group of the photomask is completed, the photomask being formed by arranging a plurality of types of mask pattern groups corresponding to the exposure patterns at predetermined intervals in the conveying direction of the object; and

a step of performing an exposure on a next exposure area on the object by the other mask pattern group,

wherein a moving speed of the photomask is controlled so that a moving distance of the object is longer than a moving distance of the photomask in a period of time from when the photomask begins to move to switch the one mask pattern group to the other mask pattern group to when the photomask stops.

2. The exposure method according to claim **1**, wherein the moving speed of the photomask is controlled to be switched to an acceleration phase in which the photomask is accelerated from a stopped state to a predetermined speed, a constant speed phase in which the photomask moves at the predetermined speed, and a deceleration phase in which the photomask decelerates and stops.

3. The exposure method according to claim **2**, wherein the moving speed of the photomask in the constant speed phase is faster than the constant conveying speed of the object.

4. An exposure apparatus for forming a different exposure pattern on each of a plurality of exposure areas arranged on an object to be exposed at predetermined intervals in a conveying direction of the object while conveying the object at a constant conveying speed in one direction, the exposure apparatus comprising:

a conveying device that conveys the object at the constant conveying speed;

a mask stage which is provided to face an upper surface of the conveying device and which holds a photomask formed by arranging a plurality of types of mask pattern groups corresponding to the exposure patterns at predetermined intervals in the conveying direction and moves the photomask by a predetermined distance in the same direction as the conveying direction of the object to switch one mask pattern group to another mask pattern group when an exposure to one exposure area on the object to by the one mask pattern group is completed; and

a control device that controls movement of the mask stage,

wherein the control device controls a moving speed of the mask stage so that a moving distance of the object is longer than a moving distance of the photomask in a period of time from when the photomask begins to move to switch the one mask pattern group to the other mask pattern group to when the photomask stops.

5. The exposure apparatus according to claim **4**, wherein the control device performs control to switch the moving speed of the mask stage to an acceleration phase in which the photomask is accelerated from a stopped state to a predetermined speed, a constant speed phase in which the photomask moves at the predetermined speed, and a deceleration phase in which the photomask decelerates and stops.

6. The exposure apparatus according to claim **5**, wherein the control device performs control so that the moving speed of the mask stage in the constant speed phase is faster than the constant conveying speed of the object.

7. The exposure apparatus according to claim **4**, wherein the photomask includes a first and a second photomask, each of which includes a plurality of sets of the plurality of types of mask pattern groups which are aligned in a line at predetermined intervals, and the first and the second photomasks are shifted from each other by a predetermined distance in a direction substantially perpendicular to the conveying direction of the object so that the plurality of sets of mask pattern groups are arranged in a direction substantially perpendicular to the conveying direction of the object at a predetermined pitch in a staggered pattern.

8. The exposure apparatus according to claim **7**, wherein, in the same type of mask pattern groups of the plurality of types of mask pattern groups of the first and the second photomasks, mask patterns located in end regions of two mask pattern groups adjacent to each other as seen from the conveying direction of the object overlap each other, and the mask patterns located in the end regions have shapes different from a shape of mask patterns located in a central portion of the mask pattern groups so that a predetermined amount of

exposure is obtained by a repeated exposure of the mask patterns corresponding to each other in the two mask pattern groups adjacent to each other.

9. The exposure apparatus according to claim **8**, wherein mask patterns located in an end region of the mask pattern groups of the first and the second photomasks are divided into a plurality of portions at predetermined pitches in a direction substantially perpendicular to the conveying direction of the object to be exposed.

10. The exposure apparatus according to claim **8**, wherein mask patterns located in an end region of the mask pattern groups of the first and the second photomasks are divided into a plurality of small patterns at predetermined intervals in a direction substantially perpendicular to the conveying direction of the object to be exposed and sizes of the small patterns are set so that a sum of areas of the plurality of small patterns is a predetermined value.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,207,546 B2
APPLICATION NO. : 13/495668
DATED : December 8, 2015
INVENTOR(S) : Kajiyama et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page, Item (56), line 3, “mailed Jul. 19, 2012” should read --mailed Jun. 28, 2012--.

In the claims

Claim 4, column 14, line 27, “object to by the one mask pattern” should read --object by the one mask pattern--.

Signed and Sealed this
Tenth Day of May, 2016

Michelle K. Lee
Director of the United States Patent and Trademark Office